PHONOLOGICAL AND VISUAL SHORT-TERM MEMORY CODIFICATION IN ENGLISH-MANDARIN BILINGUALS

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SUMMARY

Previous research shows that different languages determine the differential use of basic mechanisms for perceptual encoding, memory, and retrieval. However, limited research has been carried out with bilingual populations. English words seem to be codified in distributed traces at the phoneme level in short-term memory, and this can be evidenced with a proactive interference (PI) task. However, there is some evidence that Chinese words may be codified in both phonological and visual forms in short-term memory (STM). The first objective of the present study is to assess the extent to which phonological and visual codes are used for representing Chinese words in STM among English-Mandarin bilinguals. The second objective is to explore any differences between bilinguals with different language dominance in the use of these STM codes for Chinese. The experiments manipulated phonological and visual features of words and examined their influence on the degree of semantic PI in a short-term cued recall task. The results suggest that bilinguals process their two languages according to their language dominance. Particularly, Mixed and English dominant bilinguals showed evidence of phonological influence on PI, implicating phonological codification. There was also evidence of visual influences on PI for English dominant bilinguals, implicating visual codification. Mandarin dominant bilinguals did not show any evidence of phonological or visual influences on semantic PI, which may suggest that they have a very integrated phonological, visual and semantic memory system.

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CHAPTER 1

INTRODUCTION

The first objective of the present study is to assess the extent to which phonological and visual codes are used for representing Chinese words in short-term memory among English-Mandarin bilinguals. The second objective is to explore any differences between bilinguals with different language dominance in the use of these short-term memory codes for Chinese.

Before approaching these research questions in the subsequent chapters, this introduction will start with a discussion on the importance of studying English-Chinese bilingualism. Next, findings in visual encoding, lexical access, phonological awareness and memory for English and Chinese will be reported with the aim of providing a greater understanding of processing differences in the two languages. The introduction will also emphasise the importance of short-term memory—hereafter called STM—for language processing as well as for other cognitive processing. Then, two theoretical models of STM, Baddeley's (2000) *working memory* model and Chappel and Humphreys's (1994) *auto-associative neural network for sparse representation* model, will be briefly described as they will be used to discuss the findings from the present study. It should be noted that the present study does not attempt to empirically test any of the assumptions of these two models. These two models, the former from the symbolic processing approach and the latter from the connectionist approach, are used to situate the present study in the broader context of STM and working memory research. The introduction will end with a summary of the cognitive findings in English and Chinese and an overview of the goals of the present study.

The Importance of Studying English-Chinese Bilingualism

Describing language processing in English-Chinese bilinguals is not irrelevant. English is spoken by 312 million people and Chinese (Mandarin) by 874 million people (Central Intelligence Agency [CIA], 2006). Chinese and English are two of the most spoken languages of the world and bilingualism between these two speakers tends to be the norm. On one hand, in China nowadays many children are exposed to English, which has become an asset for accessing higher education and promising jobs. On the other hand, an increasing number of colleges and secondary schools in the U.K. offer Chinese as an elective or a compulsory subject (Neo, 2006). Besides, in places such as Singapore and Hong Kong, English plays an important role especially in education, official, and business matters, although Chinese is taught and used daily by a large part of the population.

The English and Chinese languages are particularly interesting because processing of an alphabetic and a logographic language may involve different mental operations due to the features of the different writing systems. Regarding the physical traits of Chinese, one of the prominent features is its visual complexity. Moreover, each character occupies the same square space evenly, and the space between compound characters is not differentiated from the space between simple characters. This structure allows Chinese to be written horizontally and vertically. In contrast, English words are different in length and each word forms a string. Additionally, English is only written and read horizontally. The elementary unit of reading Chinese is the character, which represents a syllable and a morpheme (McBride-Chang & Kail, 2002, p. 1393; Lin & Akamatsu, 1997, p. 371), and happens to be better at representing meaning than sound (Chitiri, Sun, Willows, & Taylor, 1992, p. 290; Chen, 1996, p. 50); but in English the elementary unit of reading is the grapheme, which represents a speech sound or phoneme (McBride-Chang & Kail, 2002, p. 1393; Chen, 1996, p. 50; Lin & Akamatsu, 1997, p. 371). Furthermore, Chinese characters are less abstract (e.g., Chinese has a relative lack of particular affixes, such as –poly, -tion, -ment, that serve to increase a word's abstractness in English; Chinese use a group of concrete words such as *turn over one's body* instead of a single word to express the English abstract word *emancipate*; finally, Chinese often lacks an abstract superordinate term such as *carry* but have many modes and means of *carrying* [Palij & Aaronson, 1992]), Chinese also has more overlap among grammatical categories (i.e., the same word, *gēn,* 跟, can play different syntactic roles depending on its meaning: *with, together, and, to follow, to go with*) and Chinese words are more optional—vs. obligatory— than English words (i.e., it is syntactically permissible to omit most Chinese function words in a sentence without impairing its grammar) (Palij & Aaronson, 1992). Chinese is orthographically deep compared to English because conversion rules between character and pronunciation are not unequivocally straightforward. Indeed, Chinese is a more homophonic and polysemic language than English inasmuch as the same pronunciation can be obtained from different characters, and the same character may have different meanings depending on the context. Chinese is also not an inflected language, and the tone of some characters changes depending on the tone of the following character. Consequently, readers of Chinese must rely heavily on the context to figure out meaning and pronunciation.

Although the same simplified Chinese script is used by all Chinese people (except in Taiwan and Hong Kong) the pronunciation varies due to the existence of different Chinese dialects. Mandarin is the spoken Chinese dialect taught in Singapore schools and is used for these experiments. In this paper, the term *Mandarin* is used for spoken language, particularly to indicate that the sample was English-Mandarin bilingual, and the term *Chinese* is used for written language as well as in the cited articles which employed the term Chinese and not Mandarin. The term *Chinese dominance* and not *Mandarin dominance* is used in this study because dominance in one language can include areas such as reading and writing proficiency.

A description of the cognitive operations of both languages in the bilingual mind will have implications on fields such as education, speech-language therapy, second language acquisition, developmental psychology, cognitive theory, neuroscience and artificial intelligence.

Processing Differences in English and Chinese

Visual Encoding

The visual information (e.g., spaces between words, letter case, and word length) enclosed in written layouts gives cues for comprehension. As an example, Chen (1996) proposes to try to read “tHiSsEnTeNcEiSdIfFiCuLtToReAd” in comparison to “This sentence is difficult to read”.

English and Chinese layouts differ enormously. English is arranged in strings of words different in length, spaces limit words, and letters can be written in different case. All these provide cues to the readers. In contrast, Chinese words are arranged by characters equally spaced and there are no physical cues to determine how many characters form a word.

It appears that different written layouts require different visual encoding. English readers show saccadic eye-movement when reading. An interesting finding is that Chinese readers do not always evince this visual scanning pattern and, when they do, they make smaller and more regular saccades than English readers (Chen, 1996). Chen affirms that the differences are due to the greater density of Chinese compared to English, since saccade length and text complexity had been negatively correlated.

Green, Rickard Liow, Tng, and Zielinski (1996) also reported different visual search procedures for English letters and Chinese characters, supporting the view that readers develop specific procedures depending on the script. Green et al. indicated that a special search function for letters emerges during reading acquisition and is different to search function for symbols (nonalphanumeric material). This special search function for letters seems to reflect procedures involved in word recognition, since words are formed by strings of letters. In their experiments, English monolinguals and English-Mandarin bilinguals had to decide whether or not a selected letter was present in a subsequent string of five letters. Correct reaction time (RT) for target position showed M-shaped letter search function in both the monolingual and bilingual samples, indicating that visual searching was faster for letters embedded in the first, the third and the last positions. However, correct RT for Chinese character (target) position showed a U-shaped search function, like correct RT for nonalphanumeric material, indicating that correct recognition was faster when the character was inserted in the third position, whereas characters inserted in the first and fifth position took longer to be recognised. The authors argue that these findings suggest that search procedures are adapted to the features of the script, that is, people process letters and Chinese characters differently.

Moreover, all the findings on visual encoding suggest that if English and Chinese readers are using different strategies at encoding, it is probable that there are differences in other more complex processes such as reading or memorising.

Lexical Access

After visual encoding, visual lexical access—or word recognition—is the subsequent cognitive operation carried out at processing written words.

English word recognition is phonologically mediated. *Standard phonological priming*, *masked priming*, and *backward masking* paradigms demonstrate phonological recoding (Wu & Liu, 1996; Brysbaert, 2001). In the standard phonological priming procedure, a prime (word or pseudoword) is presented immediately before a target word; only those primes which are homophones (e.g., brane) of the target (e.g., brain), are expected to facilitate recognition of the target. The difference between the standard priming and the masked priming procedure is that, in the latter, the prime is displayed very briefly (40-50 ms) so that participants are not aware of it, but the presence of the prime usually facilitates target recognition. In the backward masking procedure, the prime is presented very briefly, immediately after the target. As in the masking task, participants are not conscious of the prime but when the prime is a homophone pseudoword of the target, target words are recognised faster (Brysbaert, 2001; Wu & Liu, 1996).

In Chinese lexical access, phonological recoding has been demonstrated with standard phonological priming experiments (Wu & Liu, 1996; Cheng, 1992). However, priming effects are also revealed when the prime is graphically similar to the target. Chen, Yung, and Ng (1988) found that orthographic similarity affected character recognition more than phonological similarity. Sun (as cited in Chitiri et al., 1992) argued that native readers of Chinese are very efficient at integrating phonological, visual and semantic information: In a written context-free word recognition task, Sun found that native Chinese speakers were not affected by the graphic, phonological, or semantic foils included in the experiment to study interference in word recognition, but non-native Chinese speakers made interference errors particularly for graphic foils. Furthermore, masked priming and backward masking tasks have not replicated the phonological priming effect found in English (Hong & Yelland, 1992; Perfetti & Zhang, 1991). Indeed, Perfetti and Zhang found that visually similar character-primes facilitated word recognition. However, phonological priming effects start being observed when primes are exposed with longer times in phonological priming tasks (50 ms and longer), and in backward masking tasks (60 ms for the target and 40 ms for the prime), suggesting that Chinese characters are firstly processed visually and subsequently processed phonologically (Tan & Perfetti, 1998).

The tasks in priming experiments are *lexical decisions* and *naming.* The lexical decision task (LDT) requires participants to distinguish words and nonwords, by pressing appropriate buttons on a response box. In naming tasks, participants read aloud words or nonwords. Dependent variables are error rate and RT. In English, monolingual participants take longer to respond in LDTs than in naming tasks. Hence, researchers (Chen, 1996; Wu & Liu, 1996) have suggested that, at naming, English speakers engage in recoding written words into sounds automatically without lexical access, that is, without accessing word meaning. However, in deciding between a word and nonword in LDT, participants need to access meaning, resulting in longer RTs. Contrary to English, RTs in Chinese LDT are faster than in naming (Chen, 1996). These results suggest that Chinese—unlike English—participants need to know the meaning of the character in order to be able to pronounce it, so lexical decision is made a priori, before recoding phonologically. Hence, RTs in Chinese support the direct visual access hypothesis, which refers to the direct access from orthography to meaning (Chen, 1996, p. 54).

Standard phonological priming experiments are criticised (Chen, 1996; Liu 1997) because they seem to elicit phonological coding irremediably. For example, in naming tasks, participants have to read targets aloud, so phonological recoding is unavoidable. Once the participants phonologically recode targets, they would automatically continue the same procedure and would recode primes into phonological code, even though they are not requested to read aloud the prime words. In LDTs, the participants may recode phonologically because the sound of the targets—and not only its physical characteristics—help the participant to better discriminate between a word and a nonword. Once the participant is engaged in phonological recoding whilst performing a LDT, he or she would recode phonologically targets and primes. One way of surpassing the limitations of the phonological priming experiments, and gauge phonological mediation without requiring it directly, is employing a semantic-decision task. In this type of task, participants are given a category name (e.g., flower) and have to decide whether words rapidly presented are members of the category. Many of the targets are members (rose), many are homophonic words (rows) and many are control words (cat). In English, the fact that homophonic words are more difficult to discard suggests phonological recoding. In contrast, Chen (1996) found graphemic interference in semantic categorisation tasks in Cantonese. Moreover, the works of Chen, Flores d'Arcais, and Cheung (Cantonese), and Leck, Weekes and Chen (Mandarin) also showed not only homophonic but graphemic interference (as cited in Liu, 1997). That is, participants took longer to respond to targets graphically similar to an example of the category than to a homophonic or control one.

Another important difference in word recognition due to the features of the script is the directionality of the access process. Marslen-Wilson (1989) advocates that words are recognised or accessed from left to right. Employing Dutch—a West Germanic language such as English (Harris & Nelson, 1992)—in priming experiments, Marslen-Wilson showed that the first letters of a prime word activate lexical representations, facilitating recognition. Moreover, primes which rhymed but mismatched word-initially did not prime the target words. In Chinese, however, Zhou and Marslen-Wilson (1997) found that target identification was impaired—resulting in longer latencies—when primes and targets share homophonic first character. Moreover, Peng, Li, and Yang (1997) found that Chinese compound-character identification is not serial but it starts with the second radical. In their second experiment, Peng et al. created forty compound pseudocharacters and manipulated radical position legality. In particular, they expected short RTs for pseudowords in which the first radical was illegal if word recognition was a serial searching process; however, they found that RTs and the pattern of errors depended on the second radical.

Furthermore, Marslen-Wilson (1989) employed a cross-modal priming task in Dutch, in which the prime was presented auditorially whilst the target was presented visually. The fact that a written word can be primed phonologically by a word presented auditorially, supports the phonological recoding hypothesis. However, Chen and Cutler (1997) did not find this cross-modal priming effect in Chinese, this finding would support the hypothesis that reading Chinese words is not necessarily phonologically mediated.

In summary, the English lexical access findings suggest that automatic phonological recoding is a frequent mental operation that occurs regardless of the nature of the task. However, Chinese is only recoded into phonological form in tasks that require phonological recoding, such as naming tasks, phonological recoding is postlexical and graphemic characteristics of the words play an important role at recognition. These differences are conceivable because less than 35% of complex characters with phonetic components provide correct pronunciation (Chen, 1996). Moreover, although 80% of Chinese characters are formed by compounding sound-cuing phonetics and meaning-conveying radicals, the relationship between phonetics and sounds in actual characters is ambiguous (Wu & Liu, 1996). Moreover, Tan and Perfetti (1998) suggested that phonology in Chinese is activated along with the complete identification of orthographic information. It might also be activated earlier than semantics—and probably influence meaning activation—but this does not imply that phonology mediates access to meaning necessarily. They also indicated that the high degree of homophony of Chinese characters makes it difficult for phonetic traces to access the meaning of words. In contrast, in English, phonology can be assembled prelexically and mediates access to meaning.

While the findings on word recognition can provide clues on memory codification, it is important to note that care needs to be taken when generalising among different cognitive processes. For example, Seidenberg's (1985) results on Chinese and English word recognition support the dual-route and parallel interactive access in which high frequency words seem to be recognised on a visual basis and low frequency words seem to demand phonological recoding. Surprisingly, Seidenberg's findings are the reverse found for memory for Chinese words (Hue & Erickson, 1988): Memory for high frequency words seems to be stored in phonological form, and memory for low frequency words seems to be stored in visual form. Discussion on this finding is deferred till the memory section (pp.13-17).

Phonological Awareness

Phonological awareness is the skill to attend to, detect, and manipulate the sound units of words independently of their meanings. Also, it involves the ability to organise the phonological representation of a word as a sequence of phonemes (Swan & Goswami, 1997). Examples of tasks used to measure phonological awareness are manipulation of phonemes, phoneme identification, rhyme judgment, phoneme counting, phoneme deletion, and so forth.

Phonological awareness facilitates reading, spelling and phonological recoding strategies, and it is acquired faster in languages with shallow orthography in which letter-to-sound conversions are regular (Rickard Liow, 1999; Harris & Hatano, 1999; De Gelder & Vroomen, 1992). Phonological awareness is also relevant to STM codification because phonological awareness facilitates correct phonological recoding and STM is phonologically based (Baddeley, 2000) and phonologically distributed (Tehan & Humphreys, 1998). Different level of phonological awareness for English and Chinese—due to their different orthography depth—might lead to a different use of phonological recoding as a strategy to code English and Chinese words. Studies carried out with children suggest that reading instructions play an important role in the development of phonological awareness (McBride-Chang, Bialystok, Chong, & Li, 2004; Rickard Liow & Poon, 1998; Ellis, 1997; Ellis & Cataldo, 1992; Goulandris, 1992). McBride-Chang et al. (2004) compared phonological awareness of Chinese children who were being taught Chinese with the support of Pinyin (the phonetic romanisation system), Chinese children learning Chinese by the look-and-say method, and English monolingual children. They found that Pinyin promotes phonological awareness but Chinese, in general, promotes more syllable awareness than phoneme awareness, contrary to English instruction methods which promote phoneme awareness. However, once children acquired a certain level of phonological awareness in Chinese, this knowledge positively affected the learning of alphabetic languages, so there is transfer across languages (Bialystok, McBride-Chang & Luk 2005; Hu, 2003).

English is a relatively shallow language compared to Chinese, so levels of phonological awareness might differ. Differences in phonological awareness may lead to different strategies at dealing with English and Chinese. Ho (as cited in Rickard Liow, 1999) found that nine-year-old Mandarin-English Singaporeans relied on visual strategies at reading, although they had acquired basic levels of phonological awareness. However, good readers of English were using more phonological strategies. This suggests that greater experience with the Chinese script leads to reliance on graphemic features at reading, but greater experience with English leads to phonological processing. Undergraduate students in Singapore, independently of their dominance either in English or Mandarin, are expected to have achieved a similar proficiency at reading English since the instructional language of schools is English. It is imperative, therefore, to know if the differences in processing (visual vs. phonological) found in children are also found in undergraduate students who are expected to be relatively good readers of English independently from their language dominance.

Memory

There are many studies on STM codification in English. However, codification in Chinese has hardly been tested. Furthermore, no study has previously compared STM codification of English and Chinese in bilinguals, and no study has contrasted STM codification between English-Mandarin bilinguals with different language dominance.

The presence of phonological traces in memory has been demonstrated in STM tasks in which participants must memorise a list of alphabetic words or nonwords. The phonological similarity effect (recall impairment due to phonological resemblance of the words to be recalled), word-length effect (trade-off between the length of the material to be stored and memory capacity), unattended speech effect (retention impairment if the task is carried out against a background of speech; in this case, speech is gaining access to a limited phonological store at the same time as the words to be recalled), the modality effect (auditory over visual recall advantage) and, finally, the articulatory suppression effect (recall impairment due to preventing subvocalising at reading) demonstrate the use of a phonological device at memorising information in alphabetic languages (for examples and further explanation of each effect, see Baddeley & Wilson, 1988; Baddeley, 1997).

Humphreys and Tehan (1999), and Tehan and Humphreys (1995, 1996, 1998) demonstrated that phonological and semantic codes are involved in STM cued recall. Phonological activation lasts approximately two seconds, whereas semantic activation lasts longer. When the recall cue subsumes two semantically related words and participants have to recall immediately, the phonological traces—that are active—make the two words distinctive from each other if their pronunciations are dissimilar.

Notwithstanding the support for phonological traces in serial STM for English letters and words, Logie, Della Sala, Wynn, and Baddeley (2000) presented in written form phonologically similar lists of words that could be visually similar (e.g., fly, cry, dry) or visually distinct (e.g, guy, sigh, lie). They also presented in written form phonologically similar lists of letters that could be visually similar (e.g., Kk, Zz, Xx) or visually distinct (e.g., Dd, Hh, Rr). Half of the lists were presented under articulatory suppression. The subjects were asked to write down the words/letters recalled in the order they were presented. Visually distinct words were recalled better than visually similar words, suggesting a visual code for retention of visually presented verbal sequences. However, Logie et al. also admitted that the magnitude of the visual similarity effect on recall is not large, compared to the impairment in recall due to articulatory suppression, which causes disruption in the mechanisms retaining the information in phonological code.

With regards to Chinese, most of the studies have focused on memory span. Digit memory span is larger for Chinese due to the fact that Chinese numbers are shorter in length and faster to rehearse than English numbers (Lau & Hoosain, 1999; Ellis, 1992; Hoosain, 1984). These results support phonological processing. However, Hue and Erickson (1988) showed that high and medium frequency character-words, with well-known pronunciations, were stored in STM phonologically; but low-frequency character-words with pronunciations not well-known, were stored in visual form. Hue and Erickson presented their participants lists of compound characters to be recalled. The stimuli were simple characters grouped in lists of different complexity (simple: five or fewer strokes; complex: ten or more strokes) and different word frequency (high, medium and low). Participants had to recall the stimuli and write down, in order, the stimuli presented. After that, a pronunciation test was also administered. The pronunciation test assured that all the high and medium-frequency words could be pronounced, but not all the low-frequency words. Hue and Erikson found that the memory span for complex high and medium-frequency words was larger than for complex low-frequency words. Moreover, the intrusion errors at recall, for lists of high and medium-frequency, were homophonic characters (unfortunately, Hue & Erikson did not provide examples for intrusion errors). In contrast, for lists formed by low-frequency words, the intrusion errors tended to involve characters visually similar and simpler to the words in the list. Hue and Erikson's results suggest that high and medium-frequency words are recoded phonologically in STM and visual complexity makes characters distinctive among each other, facilitating retrieval. However, low-frequency characters appear to be stored in visual memory, probably due to the impossibility of recoding phonologically those stimuli (phonological traces not available). The fact that the intrusion errors, for lists made of low-frequency words, were simpler (less strokes) than the to-be-recalled stimuli suggest that visual memory could not retain all the visual information embedded in complex low-frequency words. Additionally, Hue and Erikson's third and fourth experiments, showed that a phonological interference task, between the stimuli presentation and retrieval, impaired recall of high and medium-frequency words but not low-frequency words. However, a visual interference task only impaired the recall of low-frequency words. Hue and Erikson's results show that word frequency and the capability of pronunciation affect recall. It also shows that visual complexity facilitates recall of pronounceable high and medium-frequency words, so visual codes are very important in memory for Chinese words.

Moreover, Flaherty (1997) found that visual memory for Japanese Kanji, and for abstract and nonsensical designs correlated positively and significantly with reading proficiency of Japanese Kanji in adult learners of Japanese. Chen and Juola (1982) suggested that logographic characters produce significantly more visual information in memory compared to English. In Chen and Juola's study, Chinese and English speakers had to memorise written lists of words in Chinese or English, respectively; after that, they were presented new words that could be graphemically, phonemically, or semantically similar to a word on the previously studied list and they had to decide if the new word was graphemically similar, phonemically similar, or semantically similar to any word previously studied. Only the Chinese participants responded accurately and rapidly in the graphemic recognition task. The results suggest that graphemic features of Chinese characters are particularly important for STM codification. Spatial memory also seems to be of critical importance in Chinese character processing; Tavassoli (2002) asked English monolingual speakers and Chinese bilinguals—but dominant in Chinese—to read words/characters displayed sparsely on a sheet of paper. Tavassoli found that Chinese speakers recalled the position of the characters in the space better than the English sample did for words; however the overall character/word recall was similar for both groups. Visual and spatial memory has not been related with competency in alphabetic languages.

Another interesting difference between English and Chinese speakers in STM is the modality effect. Auditory presentation results in higher recall than visual presentation for the last words of a list in English (Penny, 1989; Crowder & Greene, 2000; Baddeley, 2000). No significant modality effects as a function of presentation modality are found for the rest of the list. However, Hue, Fang, and Hsu (1990) found that recall of Chinese characters presented visually was better than those presented auditorally for the *prerecent* part of the list (all positions prior to the most recent positions). One feasible conclusion that can be drawn from Hue et al.'s results is that the last items of a list seem to be stored in phonological code, in Chinese and English. However, in Chinese the visual traces maintain salient, maybe as a strategy to discern among characters since Chinese is a very homophonic language.

The results on memory suggest that English is recoded mainly phonologically but Chinese can be stored phonologically and visually too.

To summarise, this brief review of several studies on memory, visual encoding, lexical access and phonological awareness indicate that there are processing differences due to the characteristics of English and Chinese. The present study will focus only on investigating STM processing.

Short-term memory, Language and Other Cognitive Processes

STM is critical for language processing because language processing must deal with symbols produced and perceived over time, so temporary storage is a very important part of comprehension (Carpenter & Just, 1989).

The term STM started being used in the sixties to describe a system able to retain external information in a special format for a brief period of time while being transferred into a permanent system (long-term memory, LTM). Although STM was intuited to be related to more complex cognitive operations, there was no experimental research in this issue until the seventies, when Baddeley and Hitch (1974) tried to discover whether thinking and comprehension depended on STM capacity. They designed experiments that showed that reasoning and comprehension were impaired by concurrent STM load, but the impairment was not dramatic, concluding that memory could be composed by multiple subsystems. Consequently, a broader meaning of STM was adopted to define a limited capacity system that held and manipulated information in a special format while performing cognitive tasks such as learning, retrieval, comprehension or thinking. Baddeley and Hitch (1974) named this memory system working memory (WM). Daneman and Carpenter (1980), and Turner and Engle (1989) created complex tasks, such as the reading span task and the operation span task, with the aim of measuring WM capacity. In complex tasks, participants are required to undertake a mental operation (reading, arithmetic, etc.) whilst memorising. From then onwards, and for some researchers, the term WM referred to information processing as a trade-off between storage and mental operations. The term STM remained to refer to a system of limited capacity in time and space; STM tasks usually require participants just to memorise lists of words (simple word span test). However, the terms WM and STM are frequently used interchangeably.

Performance on simple span tasks has been related to language. Particularly, phonological STM—STM for sounds—is useful to predict vocabulary acquisition because the mechanism underlying phonological STM determines the quality of the phonological representations, capacity to retain phonological information, and the rate of information loss (Jarrold, Baddeley, Hewes, Leeke, & Phillips, 2004; Baddeley, Papagno, & Vallar, 1988). Phonological STM also predicts phonological awareness (Gathercole & Baddeley, 1993). Additionally, La Pointe and Engle (1990) employed simple and complex memory tasks and demonstrated that the simple STM span—and not only the complex span—predicted language comprehension, concluding that complex and simple span tasks may not be greatly different in what they measure.

In regards to other cognitive processes, studies using STM tasks disclosed the interactions between LTM and STM. For instance, semanticity, word frequency, and phonological similarity neighbourhoods—all properties attributed to LTM—proved to affect STM span (Goh & Pisoni, 2003; Roodenrys, Hulme, Lethbridge, Hinton, & Nimmo, 2002; Schweickert, 1993; Hulme, Maughan, & Brown, 1991). The use of STM tasks also exposed the modality effect, that is, the existence of differences in recall due to visual or auditory presentation (Penney, 1989; Hue, Fang, & Hsu, 1990). Besides, Cowan et al. (1998) studied information processing ability by measuring interword pauses durations at retrieval in STM span tasks. The interword pauses at retrieval seemed to reflect capacity for searching through the STM representation of the list learnt.

Additionally, the *retrieval cue* in STM tasks shed light on the mechanisms of STM. Nairne (2002) stated that STM recall is always cue driven. As evidence, Nairne proposed that lexicality, concreteness, and semanticity effects in STM attest that cues from LTM are used to redintegrate information in STM. Moreover, the pattern of errors observed in serial recall shows that position of the words in the list seems to be used as a cue for recall, typical errors are protrusions—intrusion of one item which had occurred at the same position in previous trials—and transposition between contiguous items in the list. Moreover, participants tend to recall lists in serial order in free recall tasks, indicating that order is a cue at recall. In addition, the *release* from proactive interference (PI) phenomenon (Wickens, 1970) certifies the strong relationship between PI and cue-driven recall. In serial STM tasks, PI results in a recall impairment due to the interference of words learnt in previous lists and the list of words being retrieved. PI increases rapidly when the lists to be recalled are made from the same pool of words, or the words pertain to the same category (e.g., animals). However, switching to a new category (e.g., flowers) improves recall dramatically, demonstrating a release from PI. All the evidence provides support for cue-driven recall and some models of STM (e.g., Nairne's *feature model* and Brown, Preece, and Hulme's *oscillator-based memory for serial order* as cited in Nairne, 2002) propose no role for decay in favour of interference to explain the mechanisms of STM.

The experiments carried out in the present study employed a variation of simple memory tasks: A cued recall task. Tehan and Humphreys (1996) demonstrated that the characteristics of the cue determined PI. They configured lists of words divided into two blocks made of four words each. A to-be-remembered target word was always inserted in the second block. The first block could or could not contain a foil word related to the cue (see Figure 1.1). Participants were always requested to respond with a word from the second block that was related to a particular cue. When a cue (e.g., type of juice) subsumed a foil word and a target word in the two-block list (e.g., *orange* and *carrot*, respectively), interference of the foil (orange) was observed at recall. However, no interference was evident when the cue (e.g., type of vegetable) subsumed only the target (carrot).

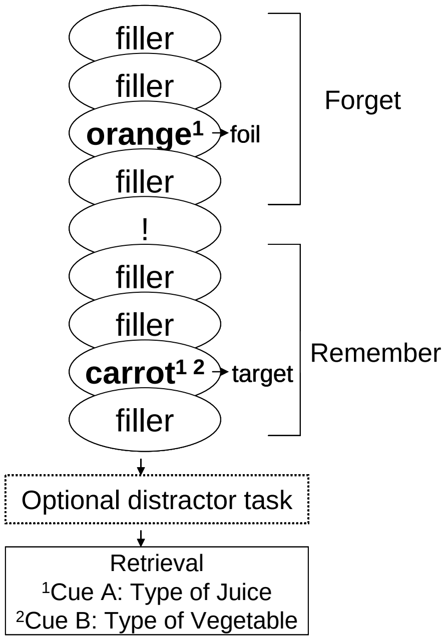

Figure 1.1. Relationship between cued recall and proactive interference.
[1] Cue A *Type of Juice* causes PI. *Orange* interferes with recall of *carrot*.
[2] Cue B *Type of Vegetable* does not cause PI.

Goh and Tan (2006), using Tehan and Humphreys's (1998) experimental design, obtained similar results concluding that PI is evidenced at retrieval and PI is set by the cue. Furthermore, Goh and Tan manipulated the context in which the foil was inserted, by inserting filler words phonologically or semantically similar to the foil (see Figure 1.2), and found that strengthening the foil context with similar words increased PI but only if the cue subsumed both foil and target. Hence, context codification is also important in memory since it can potentially increase PI effects.

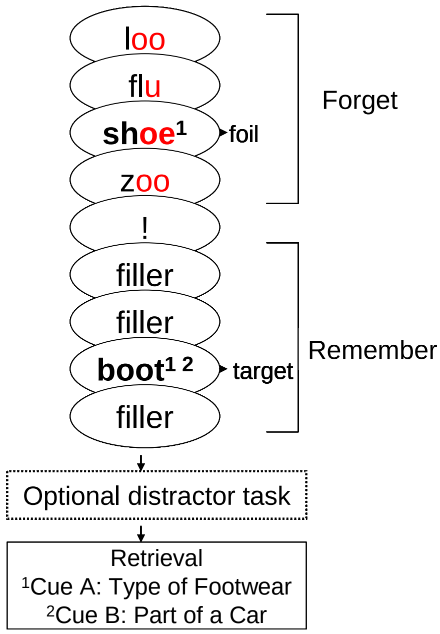

Figure 1.2. Relationship between cued recall and proactive interference with foil inserted in phonological context.

[1] Cue A *Type of Footwear* causes PI. *Shoe* interferes with recall of *boot*.

[2] Cue B *Part of a Car* does not cause PI.

The experimentation on STM has shown that STM is vital in cognitive processing. As language processing—as a part of cognitive processing—seems to depend particularly on STM, it is critical to figure out how different languages are represented in STM and finding out how bilinguals process two languages.

The design of Tehan and Humphreys's cued recall tasks were employed in the present study because PI effects are proving to be very useful for constraining assumptions concerning representation, storage, and retrieval (see Tehan & Humphreys, 1995, 1996, 1998). PI effects have evidenced the phonological and semantic properties of STM for English words but no study has shown the phonological and semantic properties of STM for Chinese making use of PI effects. Moreover, the visual complexity of Chinese might lead to visual PI effects that are not detectable in English. Thus, PI effects should be useful to describe the visual, phonological and semantic properties of Chinese and investigate processing differences in STM for English and Chinese.

Theories and Models of STM

Symbolic Information Processing Paradigm

The first models of memory created in the sixties (e.g., Atkinson & Shiffrin's model) conceived STM as a buffer of information, and also stressed the bottom-up and linear structure of memory, and the differences and interactions between STM and LTM. However, a turn in the interest towards the processes of STM led to the conception of new models such as the Broadbent's *Maltese cross* model (1984), Cowan's model (1988), and the Baddeley and Hitch's WM model (1974) (as cited in Ruíz-Vargas, 1991). These models kept the modular representation of the memory but broke with the strict sequential directionality of the information. They also conceived a central system of mental processing in which information from different systems converged. These models are known as models of WM.

Nowadays, many models are embraced by the WM paradigm. Generally, it is assumed that mental processing is executed under limited cognitive resources; the WM model provides account of individual differences in on-line cognition according to the capacity and processes of its components.

Baddeley and Hitch's (1974) WM model was one of the pioneers and the most influential in memory research. Figure 1.3 shows the latest version of Baddeley's working memory model (Baddeley, 2000), which is formed by the central executive, the phonological loop, the visuospatial sketchpad and the episodic buffer. The central executive is an attention device which supervises the rest of the components, also called slaves. It also activates representations within long-term memory to find a schema able to simplify the information, so the WM system does not get overloaded. The phonological loop is the module that temporally stores and maintains, by subvocal rehearsal, sequential phonological information; it also recodes graphemic information into phonological code. The phonological loop is used in comprehension, learning to read, and acquisition of vocabulary. The visuospatial sketchpad is formed by two subcomponents: the visual cache (capacity for retaining visual patterns) and the inner scribe (capacity for retaining sequences of movements). Finally, the episodic buffer is where all the information from different modules integrates.

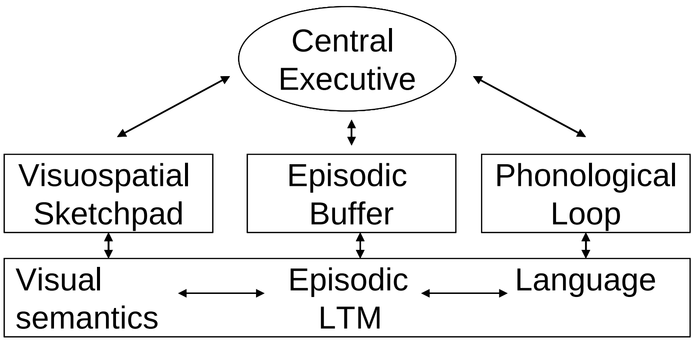

Figure 1.3. Working Memory model (Baddeley, 2000).

The success of Baddeley's WM model throughout the last thirty years is because the components and processes are easily explained, and are cognitively and anatomically differentiated (Henson, 2001). Moreover, the WM model accounts for a multitude of memory effects in healthy and clinical populations.

Short-term memory cued recall is supported by the different components of WM. In a cued recall task, words would be recoded phonologically by the phonological loop; some graphic information would also be codified by the visuospatial sketchpad. Moreover, the central executive would also activate information related to the words that is stored in LTM. The information from all the modules would combine in the episodic buffer. When a recall cue is provided, it is possible that the recall cue accesses LTM (semantics), and activates words related to the cue. Then, recall would be the result of the performance of the central executive centring its resources in matching words activated in LTM by the cue with the words stored previously in the episodic buffer.

Connectionist or Neural Network Paradigm

Neural network, connectionist and parallel distributed processing (PDP) are models that represent items as vectors of features. They are also inspired in the pattern of neural activity. Memory epiphenomena are the result of the pattern of activation, decay, and inhibition of nodes distributed in layers specialised for different functions. Between input and output there are layers made of nodes (hidden nodes), their function is to map a vector of activations at its input layer to a vector of activations at its output layer (Chappel & Humphreys, 1994). The number of hidden nodes is less than the units for inputs and outputs, so information has to go through a process of transformation and regularisation; a *parallelism* could be the thalamus (hidden unit), which receives information from different sensorial systems (inputs). In the thalamus there would be regularisation of information by transforming and integrating it, and subsequently the thalamus would send the transformed information as specific information to cortical different areas (outputs) (Carlson, 1993). Models are mathematically based and tested through computer programmes that simulate memory.

One of these models is the *auto-associative neural network for sparse representations* (Chappel & Humphreys, 1994). This model was created for analysis and application to models of recognition and cued recall, but also accounts for similarity effects, dissociation between recognition and frequency judgments, and proactive and retroactive interference effects. It has been used in monolingual contexts and it is the model adopted by Tehan and Humphreys (1998) in their studies of STM cued recall. This connectionist model consists of a group of units with dissimilar scalar activation arranged in different layers. Units and layers are connected by weights (see Figure 1.4). Activation is determined by inputs inside and outside the net. These units represent neurons and the activations synapses, a parallelism of a biological network. Changes in the network (learning) are due to modifications of the weights between units.

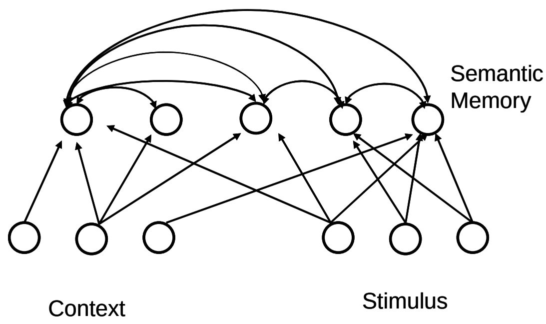

Figure 1.4. Cued-recall network architecture (Chappel & Humphreys, 1994).

In Figure 1.4, the stimulus units store preexperimental associations between peripherical representations (features initially activated by auditory or visual stimulation) and the semantic memory (central representations). The context units store experimental associations between the context and the items. The semantic memory units store meaning and experimental learning occurs here also. The main characteristic of this model is that the stimulus loses its identity at storage because storage is distributed (peripherical and central representations are represented by different vectors with a distributed associative memory connecting the two representations, Humphreys, Bain, & Pike, 1989). For example, the phonological information of the word *dog* is distributed into the phonemes /d/, /o/, and /g/. Stimuli are stored as associations represented by different pattern of connections in units and layers (phonological, visual, semantic, of the context, etc.) and retrieval is accomplished by redintegration of the traces left in those units.

With regards to a cued recall task, when the cue subsumes more than one word of a list of words previously memorised, multiple traces may be activated, thus creating interference. That is, if in a list formed by the words *ship, dog, car, tool, son, rat, map, pen*, and the recall cue is the *last animal in the list*, it is possible there will be interference between *dog* and *rat*. The interference will be greater the more the response is delayed. Phonological unit activations last about two seconds so, if the participant is requested to respond immediately, he or she will distinguish clearly that the sound *rat* was the last. However, after two seconds and with no verbal rehearsal, only semantic and context units are activated; in this case, the probability of interference will increase because phonological units stopped discerning between the two animal words.

Summary and Overview of the Present Study

English and Mandarin are two of the most spoken languages of the world and the number of English-Mandarin bilinguals is increasing rapidly. However, few studies have approached the study of word processing for this type of bilinguals. Most of the studies on word cognitive processing have been carried out with monolingual samples or bilingual samples dealing only with their dominant language (e.g., Tehan & Humphreys, 1998; McBride-Chang et al., 2004; Tan & Perfetti, 1998; Marslen-Wilson, 1998). The studies on visual encoding showed that English readers show longer and more irregular saccades than Chinese readers. English layouts also required different visual search procedures than Chinese. The studies on lexical access disclosed that, in English, phonology was prelexical and mediated access to meaning, whereas in Chinese phonology was postlexical and the visual features of the characters were critical in lexical access. The studies on phonological awareness pointed out that a greater experience with English could lead to phonological processing of written material, whereas greater experience with Chinese could lead to a greater graphemic processing because Chinese does not promote phonological awareness at phonemic level. Lastly, the studies on memory highlighted that STM for English words is basically codified in phonological form. However, visual memory seemed also be very important for Chinese characters. All these studies showed that cognitive processing is subjected to the nature of the script.

STM has been related to language acquisition, reading comprehension and other cognitive processes such as mathematical achievements. Despite the importance of STM in cognition, there are no studies comparing English and Chinese word processing in STM by bilinguals with different language dominance. Moreover, testing populations with different degrees of bilingualism might reveal processes in STM (e.g., phonological PI, semantic PI, visual PI, etc.) not detectable in monolingual populations.

The aim of the present study is to describe word codification in STM of English-Mandarin bilinguals and to explore the differences between bilinguals with different language dominance. The following experiments will examine the nature of STM codes for Chinese and English in more detail within Tehan and Humphreys' STM cued recall procedure. The design of the experiments includes two blocks of words in which a foil word (in the first block) and target word (in the second block) are semantically related, then a semantic recall cue is provided and the participant has to retrieve the target word. The filler words of the second block were manipulated in a way that they were graphically or phonologically similar to the foil. Tehan and Humphreys showed that PI effects are critical for the understanding of the mechanisms of STM. Furthermore, with this design, Tehan and Humphreys demonstrated the critical importance of phonological traces in STM codification for English words. The fact that Chinese may not be phonologically mediated makes a cued recall task—which requires semantic processing—adequate to study the characteristics of Chinese word processing in STM. Moreover, the use of a bilingual sample will help to understand the role of phonological, visual, and semantic traces for English and Chinese in STM. Experiment 1 examined whether there was evidence for phonological PI in Chinese, while Experiment 2 investigated the evidence for visual PI in Chinese. The specific predictions and hypotheses will be stated in the subsequent chapters.

CHAPTER 2

EXPERIMENT 1

Experiment 1 replicates Tehan and Humphreys's (1998) third experiment, but with Chinese words. Tehan and Humphreys created a series of trials made of four (one-block trials) and eight words (two-block trials). In one-block trials, a recall cue was presented immediately after the fourth word. In two-block trials, the cue was presented after the eighth word. The retrieval cue was the name of a category (e.g., cosmetic) and subjects had to respond with a word in the list that was semantically related to the cue (e.g., cream).

One-block and two-block trials were presented randomly. Participants had to consider all trials as a one-block trial until an exclamation mark (!) appeared after the fourth word indicating that the present trial was a two-block trial. Once the participants saw the exclamation mark, they were told to forget the first block and only concentrate on the second block because the cue only referred to the second block.

Experimental conditions were composed of two-block trials. One-block trials were created with the purpose of ensuring attention to all stimuli. If only two-block trials had been presented, participants would not have paid attention to the first block.

There were three experimental conditions (see Figure 2.1). The *no interference* condition contained two-block trials in which the first block did not contain any word related to the cue, but the second block contained the target word. In the *standard interference* condition (Tehan & Humphreys called it *interference* condition), the first and second blocks each included one word semantically related to the cue. The *phonological interference* condition (Tehan & Humphreys called it *interference + components* condition) was the same as the standard condition (i.e., semantic interference) *and* the phonemes of the foil (dog: /d/, /o/, /g/) were distributed among the filler words (/d/ in *dart*, /o/ in *mop*, /g/ in *fig*) of the second block, but not in the target word.

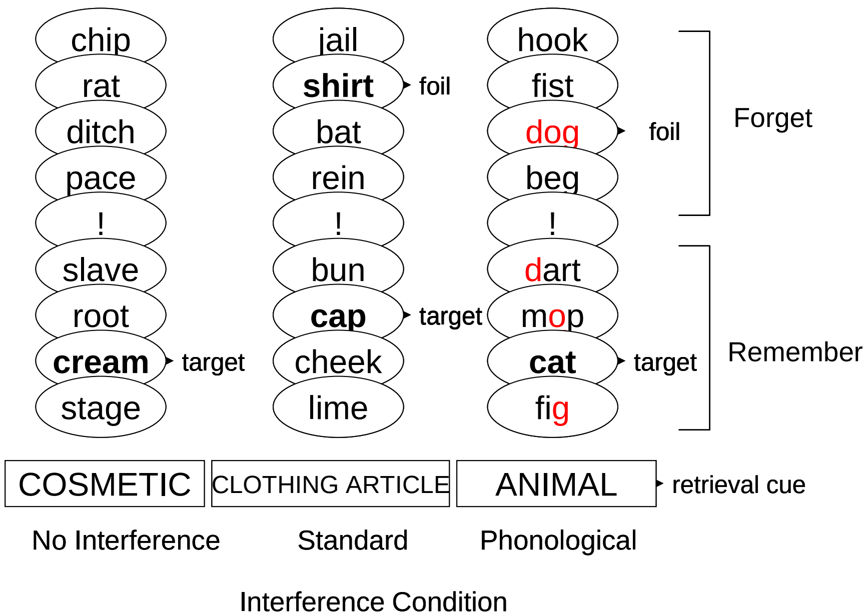

Figure 2.1. Experimental conditions in Tehan and Humphreys's (1998) third experiment.

Tehan and Humphreys (1998) demonstrated that information in STM is codified phonologically. Their participants made more interference errors (recall of the foil in the place of the target) in the phonological condition than in the standard condition, showing that the phonemes of the last block (in the phonological condition) mapped onto the foil and this facilitated its continued activation. In the phonological condition, activated phonological traces increased the interference between the foil and target. Furthermore, they demonstrated that memory is distributed because phonemes distributed among the fillers kept the foil word active.

Figure 2.2 shows my replication of Tehan and Humphreys's (1998) third experiment with Chinese characters. Notice that Hanyu Pinyin is added to show the phoneme repetition of the foil *shàng wǔ* (/sh/, /ng/, and /u/) among the fillers of the second block in the phonological condition. In the experiment, participants only saw character-words. Also, another experiment with different English words was conducted with the aim of replicating the critical difference between the standard and phonological interference conditions in Tehan and Humphreys's (1998) third experiment with English-Mandarin bilinguals.

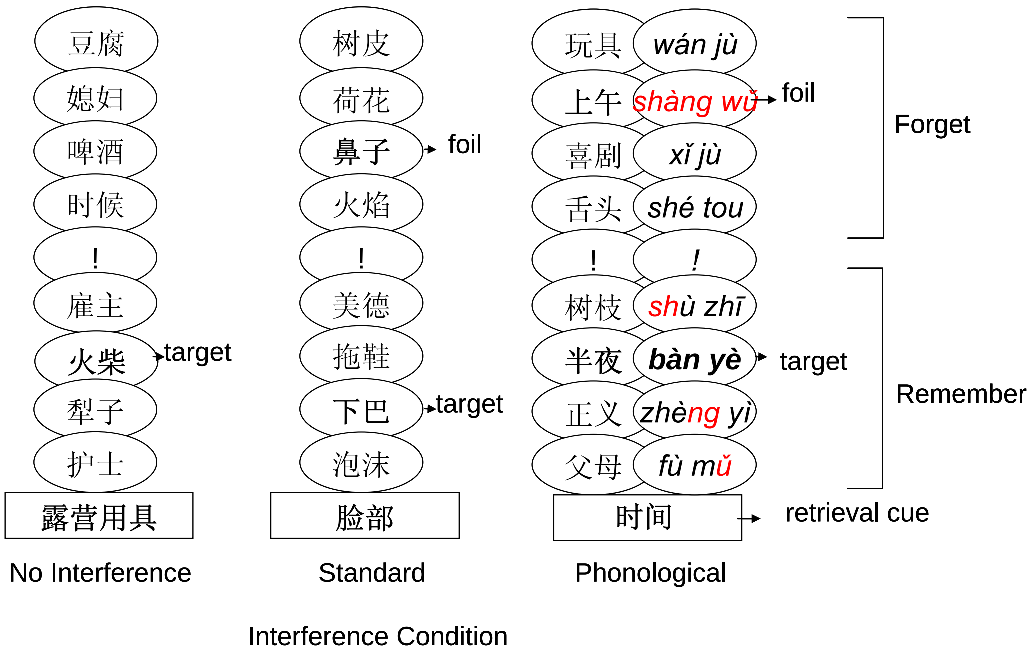

Figure 2.2. Experimental conditions in Experiment 1 (Chinese).

No interference condition. English translation from top to bottom: bean, daughter-in-law, beer, time, employer, matches (target), pear, nurse, item of camping equipment (cue).

Standard condition. English translation from top to bottom: bark, lotus, nose (foil), flame, morality, slippers, chin (target), foam, part of a face (cue).

Phonological condition. English translation from top to bottom: toy, morning (foil), comedy, tongue, branch, midnight (target), justice, parents, time of day (cue).

This immediate cued recall task may clarify some of the contradictory results obtained in Chinese language processing of written words, specifically results supporting phonological recoding of Chinese (Lau & Hoosain, 1999; Ellis, 1992; Hoosain, 1984), those supporting direct visual lexical access prior to recoding (Chen, 1996), and those supporting visual processing without phonological recoding (Perfetti & Zhang, 1991; Liu, 1997).

The main hypothesis predicts that if Chinese words—and English words—are codified and stored in distributed phonological traces, then there will be more foil interference errors in the phonological condition than in the standard condition because the phonemes in the second block will keep the phonological traces of the foil active. However, if Chinese words access meaning directly without necessarily requiring phonological recoding—also called the direct hypothesis—then the proportion of errors in the phonological condition will be similar to the proportion of errors in the standard condition.

Finally, it is possible that language dominance will determine the pattern of interference. Specifically, it is predicted that participants less proficient in Chinese—and probably more English orientated—will show phonological interference due to a greater phonological awareness and greater phonemic-based language processing. In contrast, those who are more proficient in Chinese will show interference patterns consistent with the direct hypothesis (semantic access to Chinese characters not mediated by prelexical phonological activation) so the level of interference errors in the phonological and standard conditions will be similar.

Method

Participants

The sample included 91 English-Mandarin undergraduate students from the National University of Singapore who participated for course credit. All of them had obtained a minimum score of B4 in Chinese at AO levels.

Design

Experiment 1 was designed as two separate experiments, one using Chinese words (Chinese experiment) and the other using English words (English experiment).

The Chinese experiment comprised a single within-subject independent variable (IV) (interference condition) with three levels: no interference, standard interference, and phonological interference. The dependent variable (DV) was the proportion of interference errors (foil intrusions from block 1).

The English experiment comprised a single within-subject IV (interference condition) with two levels[1]: standard interference and phonological interference. The DV was also the proportion of interference errors.

The rationale of running a parallel experiment in English was to test whether phonological PI in English immediate recall found previously with English monolinguals (Tehan & Humphreys, 1998) could be replicated with English-Mandarin bilinguals. Thus, the English experiment was a direct replication of part of Tehan and Humphreys's third experiment (1998).

Materials

Foils, targets and cues were selected from the normative data for taxonomic categories collected by McEvoy and Nelson (1982) and translated into Chinese. A total of 27 categories, 27 foils and 27 targets for two-block trials; and ten categories and ten targets for one-block trials were selected.

[1] The English experiment only contained the two critical experimental conditions, the standard interference and the phonological interference conditions, because the no interference condition does not provide information about PI effects (no PI due to the absence of the foil) as shown in previous experiments carried out in English (Goh & Tan, 2006; Tehan & Humphreys, 1995, 1996, 1998). Since the Chinese experiment has never been done before, the no interference condition was kept in order to demonstrate that the previous English studies showing no PI effects unless there was a relevant foil could be replicated with Chinese words. As there were many constraints in selecting the words for the various conditions and ensuring no semantic overlap in the English and Chinese word categories, reducing the number of noncritical experimental conditions in the English experiment was helpful in this regard.

The criteria for choosing foils and targets were that, within the same trial, both were single character or both were two-compound character words. Additionally, one-character words should be composed by three phonemes and two-character words composed by four phonemes. The foil was always a more typical instance of the category in order to maximise the interference of the foil. Nineteen participants who did not participate in Experiment 1 ranked foil and target typicality. To do so, I presented a questionnaire with names of different categories (e.g., item of camping equipment) and several examples (e.g., backpack, lantern, matches, stove, boots); they had to put the examples in order from the most typical to the less typical instance (see Appendix A, Questionnaire A). Foils were selected from words mostly ranked as the first or second most typical instances, while targets occupied subsequent rankings. The nineteen participants also had to read aloud all the words that were initially selected for the experiment and indicate which ones they were not able to read or did not know the meaning of. This was to ensure that all words were known by the participants. No word presented special difficulty.

Foils and targets were matched for word frequency based on Wang et al. (1990) counts; t-test between foils and targets was not significant, $t < 1$. Foils and targets were also equated for number of strokes, $t < 1$, as well as for number of transparent characters (characters that contain phonetic components that predict the *exact* and *correct* pronunciation of the characters; e.g., any character containing the component 平 /píng/ will be pronunced exactly as /píng/ such as in 苹果 /píng guǒ/, 评价 /píng jià/, that mean *apple* and *to assess*, respectively), $\chi^2(1, N = 54) = .13$, *ns*, (see Table 2.1).

Table 2.1. Average word frequency, number of strokes, and number of transparent and nontransparent characters (Experiment 1, Chinese).

	Characters			
	Word Frequency	Strokes	Transparent	Nontransparent
Foil	.0073 (.0109)[1]	12.89 (4.78)[1]	5 (.19)[2]	22 (.81)[2]
Target	.0071 (.0121)[1]	11.70 (4.27)[1]	4 (.15)[2]	23 (.85)[2]

Note. [1] SDs; [2] proportion.

In the phonological interference condition, the first and last phoneme of the four-phoneme foils plus either the second or the third phoneme were repeated among the critical fillers in the second block.

In order to reduce the influence of primacy and recency effects, foils and targets were located in the second or third position. Foils and targets were always inserted in the same serial position within the same trial. In one-block trials, the targets were inserted in any position.

Critical and unrelated fillers were obtained with the help of a Chinese-English on-line dictionary (“Xiao ma ci dian”, 2005). Fillers matched the characteristics of the foils and targets of each trial; that is, one or two-compound characters with three or four phonemes, respectively.

The 27 categories for the critical two-block trials were divided into three lists of nine category retrieval cues and foil-target pairs. Each list was assigned to one of the three experimental conditions (described in Figure 2.2). For counterbalancing purposes, three versions of the experiment were created using a partial Latin-square procedure to rotate the lists through the different experimental conditions across different participants[2]. Table A1 in Appendix A shows the critical stimuli employed in the Chinese experiment.

For English words, foil and target typicality rankings were obtained from the taxonomic categories collected by McEvoy and Nelson (1982). As before, foils were selected to be more typical instances in order to maximize PI. Foils (M = 33.33, SD = 38.29) and targets (M = 3.11, SD = 2.56) typicality rankings differed significantly (grades of freedom adjusted due to inequality of variances), $t(17.15) = 3.34$, $p < .05$, $d = .78$. Ten more categories were selected as one-block trials. The categories used were distinct from the ones used in the Chinese experiment. The rest of the details are common to the Chinese version. Foils (M = 25.29, SD = 40.04) and targets (M = 47.43, SD = 72.30) were equated on word frequency based on Kucera and Francis (1967), $t(29) = 1.08$, *ns*. Table A2 in Appendix A contains the critical words employed in the English experiment.

Procedure

Presentation of four and eight-word lists were randomly interspersed and participants noticed that a trial was composed of eight words only when an exclamation mark (!) appeared after the fourth word. Once they realised that a trial was formed by eight words, they were instructed to forget the first four words and only pay attention to the next four words in order to respond to the cue. The cue was presented immediately after the fourth or eighth word. The cue was displayed in green in the Chinese experiment, and in upper-case in the English experiment. Words were presented in black and in lower case.

[2] For any individual participant, words were shown only once and never repeated across trials or conditions.

The experiment was programmed with E-Prime 1.1. A trial sequence began with a “READY” sign displayed on the computer monitor for 2000 ms. Then, stimuli were displayed at a rate of one word per second. After the fourth or eighth word, a recall cue indicated that they should write the response immediately.

Participants wrote their answers on an answer sheet and were requested to answer all trials, or mark a cross if they were unable to recall the target. Participants pressed “enter” to start the next trial. In the Chinese experiment, participants were allowed to write in Hanyu Pinyin whenever they felt incapable of writing the characters.

Participants were assigned randomly to one of the three versions of the Chinese experiment and one of the two versions of the English experiment (as explained previously, the versions were obtained through a partial Latin-square procedure that rotated the lists through the different experimental conditions across different participants). The presentation order of the Chinese and English experiments was counterbalanced. Both the Chinese and the English experiments were preceded by four practice trials. Once the experiment was over, participants were asked about their academic scores in Chinese at AO levels. The session lasted 30 minutes.

Results

The mean proportion of correct recall in the one-block trials was .78 (*SD* = .17) for the Chinese experiment, and for the English experiment was .93 (*SD* = .11). A higher proportion of recall in one-block trials in the English experiment—in comparison to the Chinese experiment—would indicate that, in general, the task in

English was easier than in Chinese; reading in English might be a more automatic process than Chinese given the characteristics of the education system in Singapore, wherein English is the main language used for instruction, and this could have affected the average correct recall. However, this is a speculation since automaticity or proficiency in English was not measured. Attention to one-block trials assured that participants had processed the first block of words in two-block trials, processing of the first block in two-block trials was critical in order to obtain PI effects. Thus, participants who scored less than 2 standard deviations from the mean of one-block trials in the Chinese experiment were eliminated, as such participants may not have paid attention to the first block of four words. Four participants failed to meet this criterion, and the rest of the analyses were performed with the remaining 87 participants.

From the 87 participants, only 62 participated in the English experiment due to technical problems with the English experiment at the start of data collection.

In the Chinese experiment, the results of two trials were also discarded in the analyses because it was subsequently discovered that the cue subsumed not only the target but another filler of the second block.

The DV was response probability of interference errors. Interference errors refer to the recall of the foil in the place of the target. Therefore, interference errors are the only direct evidence of PI[3]. Response probability of interference errors refers to the proportion of interference errors for each experimental condition. For example, if a participant committed three interference errors in the phonological condition and

[3] Other errors such as omissions (no response) and intrusions (extralist intrusions) were not examined. Omissions cannot gauge interference because there is no response, the participant may have forgotten foil and target, or the participant may only remember the foil but he does not respond because he is asked to report only the target word. Intrusions do not denote PI because the intruded word was not presented previously in the list.

the phonological condition contained nine trials, his or her response probability for the phonological condition was 3 (interference errors)/9 (trials) = .33.

If memory was codified in distributed phonological traces, this should be manifested in significantly more interference errors in the phonological condition compared to the standard condition. Because all of the experimental hypotheses stated in pages 33-34 comprised theoretically motivated predictions that involved differences in a specific direction, planned comparisons using one-tailed paired *t*-tests examining the difference between the phonological and the standard conditions were conducted to directly test theses hypotheses instead of omnibus analyses of variance (ANOVA)[4]. These analyses were done separately for the Chinese and English experiments[5].

The proportion of interference errors across the experimental conditions for the Chinese and English experiments is shown in Figure 2.3 and 2.4, respectively.

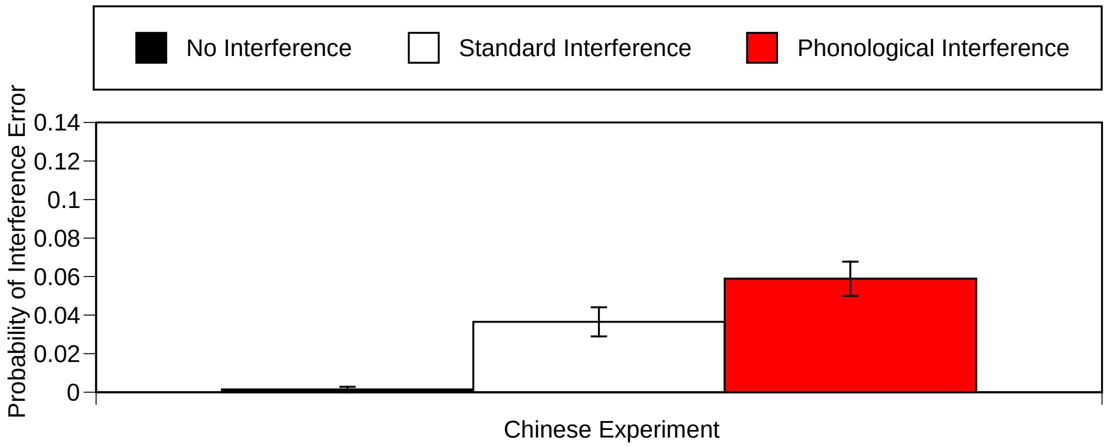

Figure 2.3. Average probability (+*SE*s) of interference errors in the Chinese experiment (Experiment 1).

[4] Tehan and Humphreys (1998) also used planned comparisons testing specific differences to probe their hypotheses on PI.

[5] Interference levels between the Chinese and English experiments at each of the phonological and standard conditions (i.e., across experiments differences for each condition) were not relevant to the hypotheses and so were not examined. In addition, a mixed ANOVA design was not appropriate since the Chinese experiment contained three levels while the English experiment only had two levels. Moreover, not all the participants in the Chinese experiment participated in the English experiment.

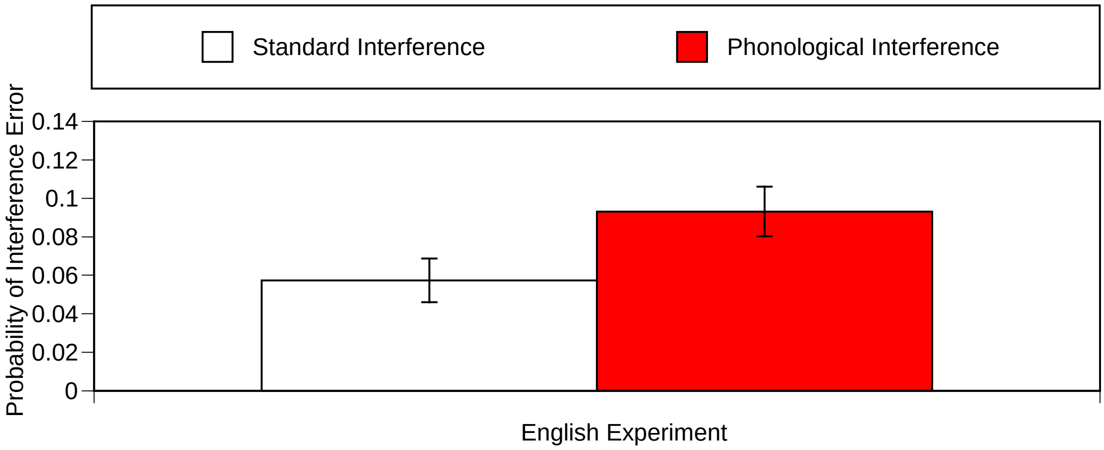

Figure 2.4. Average probability (+*SE*s) of interference errors in the English experiment (Experiment 1).

For the Chinese experiment, there were, as expected, virtually no interference errors ($M = 0$, $SD = .04$) in the no interference condition. This result demonstrates that the finding of no interference errors unless there was a relevant foil, previously reported with English words (Goh & Tan, 2006; Tehan & Humphreys, 1998, 1996, 1995) was replicated with Chinese words.

Due to the lack of errors in the no interference condition, it would therefore not be appropriate to test this condition against the others as there is no variance in the former. So, the critical comparisons were between the standard condition and the phonological condition. For the critical planned comparison, there were significantly more interference errors in the phonological condition ($M = .06$, $SD = .08$) than in the standard condition ($M = .04$, $SD = .07$), $t(86) = 2.29$, $p < .05$, $d = .25$.

Likewise, in the English experiment, the critical planned comparison revealed that there were significantly more interference errors in the phonological condition ($M = .09$, $SD = .10$) than in the standard condition ($M = .06$, $SD = .09$), $t(61) = 2.44$,

$p < .01$, $d = .31$. I defer comparison of the effect sizes between the present study and Tehan and Humphreys's (1998) study to the discussion section.

The main hypothesis, that predicted more interference errors in the phonological condition if Chinese and English words were codified and stored in distributed phonological traces, is supported.

The subsequent analyses explored whether language dominance would affect the pattern of interference. Particularly, it was possible that those less proficient in Chinese, and perhaps more proficient in English[6], would show phonological interference due to a greater phonological awareness and more phonemic-based language processing, whereas those more proficient in Chinese would not.

The sample was split by proficiency in Chinese according to the results in Chinese at AO levels (A or B)[7]. Table 2.2 indicates the number of participants pertaining to each proficient group for the experiments in Chinese and English.

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[6] The statement that those less proficient in Chinese may be more proficient in English is merely hypothetical. It is important to remark that English proficiency was not measured in Experiment 1. The hypothesis that those excellent in Chinese would score more A's than those poorer in Chinese (and probably more English orientated) was based on the results of a survey on bilingualism in Singapore administrated previously and with other purposes than this experiment, in which 137 undergraduate students of the National University of Singapore took part. The participants had to classify themselves *globally* (and not only pertaining to their academic proficiency in Chinese or English) as Chinese, English or mixed dominants; those who considered themselves Chinese dominants had obtained 41.2% of A's in Chinese at AO levels, whereas those who considered themselves English dominants only obtained 14.6% of A's at Chinese at AO levels. However, the percentage of participants who obtained B's in Chinese at AO levels was similar for both groups, 52.9% and 54.2% for the Chinese and English dominants, respectively (Suárez, 2005). According to the previous results of the survey, in Experiment 1 it was assumed that a greater part of those who obtained A in Chinese at AO levels could be classified as more Chinese dominant than those who obtained B's, and a great part of those who obtained B's could have had considered themselves less Chinese dominant and more English orientated, and probably more proficient in English. However, in this experiment more proficiency in English than in Chinese was not explicitly assessed.

[7] It should be acknowledged that employing only academic records (A and B) in Chinese at AO levels as a measure of proficiency in Chinese is dubious and too simple. It could have been that some participants were excellent in Chinese academically and be more English orientated. This limitation was addressed in Experiment 2, in which other measures of proficiency than academic records in Chinese were recorded.

Table 2.2. Number of participants for each level of proficiency in each experiment (Experiment 1).

	Experiment		
Chinese Proficiency	Chinese	English	Total
A	53	38	91
B	34	24	58

Figure 2.5 and 2.6 show the proportion of interference errors across the experimental conditions for each group of different proficiency in Chinese for the Chinese and the English experiment, respectively.

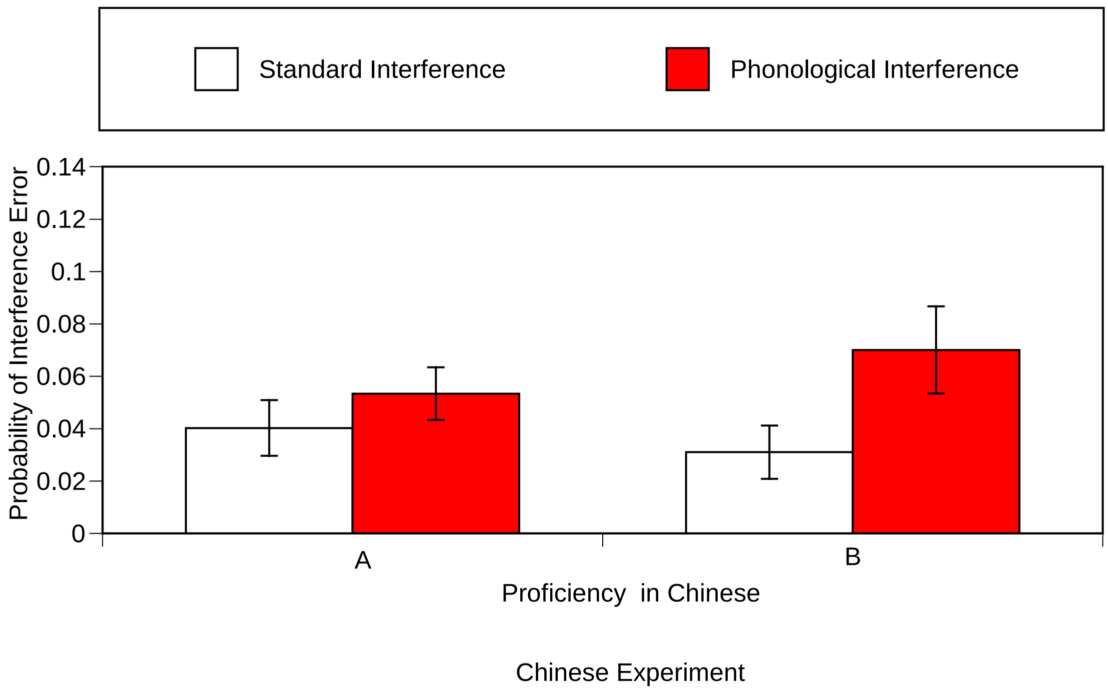

Figure 2.5. Average probability (+*SE*s) of interference errors by participants with different proficiency in Chinese in the Chinese experiment (Experiment 1).

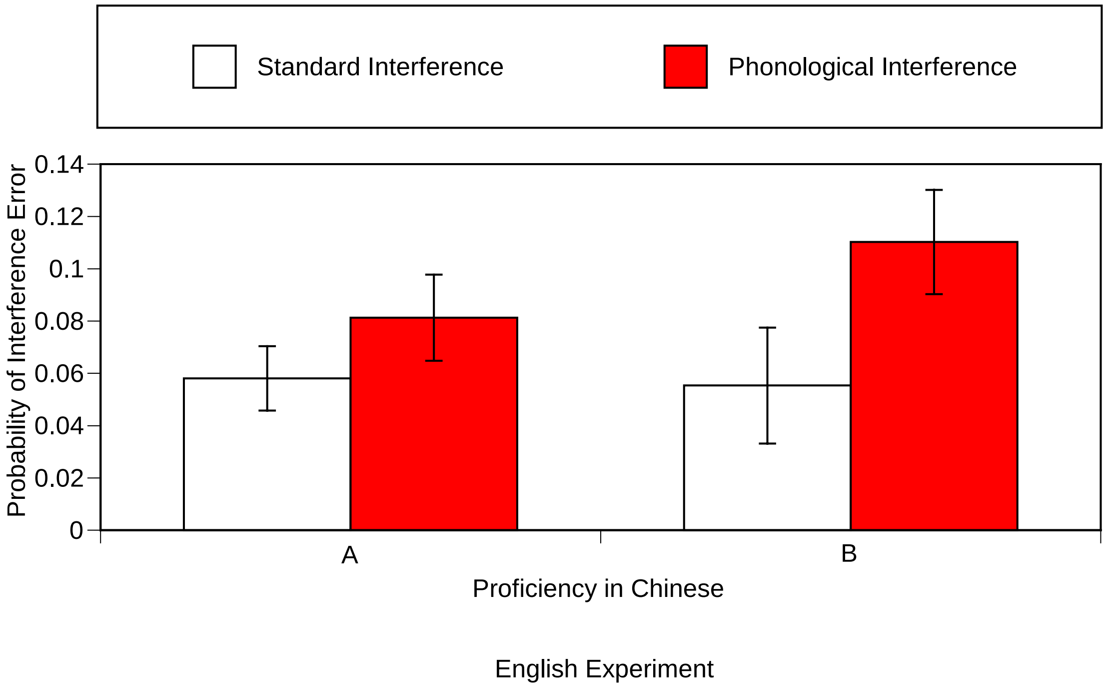

Figure 2.6. Average probability (+*SE*s) of interference errors by participants with different proficiency in Chinese in the English experiment (Experiment 1).

Similar planned comparisons[8] between the phonological and the standard interference conditions were conducted with each of the proficiency groups.

In the Chinese experiment, the group who obtained the best results in Chinese at AO levels (group A) showed the same mean proportion of interference errors in the phonological condition (M = .05, SD = .07) and the standard condition (M = .04, SD = .08), $t < 1$, d = .14. In contrast, group B (those who obtained B in Chinese at AO levels) showed a significant difference in the proportion of interference errors, they made more interference errors in the phonological condition (M = .07, SD = .10) than in the standard condition (M = .03, SD = .06), $t(33) = 2.48$, $p < .01$, d = .43.

[8] Roberts & Russo (1999, pp. 87, 226 -227) recommended running planned comparisons using pairwise *t*-tests when the effects to be tested are specified in advance. They also recommended that as long as the number of multiple planned comparisons did not exceed the number of experimental conditions minus one, no alpha-level corrections were necessary. In this case, there were 4 conditions each in the Chinese and English experiments and the number of planned comparisons for each experiment was 2.

In the English experiment, planned comparisons revealed that the participants of group A did not commit significantly more interference errors in the phonological condition ($M = .08$, $SD = .10$) than in the standard condition ($M = .06$, $SD = .08$), $t(37) = 1.38$, *ns,* $d = .22$. However, the group B participants showed a significant difference in the proportion of interference errors, they made marginally more interference errors in the phonological condition ($M = .11$, $SD = .10$) than in the standard condition ($M = .06$, $SD = .11$), $t(23) = 2.06$, $p < .05$, $d = .42$.

This supports the hypothesis regarding language dominance effects, which predicted only phonological interference by those less proficient in Chinese (and probably more dominant in English) due to a more phonemic-based language processing. Moreover, participants very proficient in Chinese seemed immune to phonological PI.

Discussion

The first hypothesis stated that phonological codification of written material as well as distributed storage of phonemic traces would be evidenced by a higher proportion of interference errors in the phonological condition compared to the standard condition. The results indicate that English-Mandarin bilinguals seem to encode Chinese characters as well as English words in phonological form in STM. The results replicated Tehan and Humphreys's (1998) findings with English words: More foil intrusions were observed in the phonological condition than in the standard condition. Phonological recoding for this type of task was not a requisite because the cue was a semantic category; indeed, it was important to access meaning. Phonological processing was not necessary as lexical access, particularly in Chinese, is a step carried out prior to phonological recoding (Hong & Yelland, 1992; Perfetti & Zhang, 1991; Chen & Cutler, 1997; Tan & Perfetti, 1998). However, the pattern of results clearly demonstrates evidence of phonological processing. The preliminary results refute the direct hypothesis, which states that meaning is accessed prior to phonological recoding in Chinese (Chen, 1996), at least as a unique language processing mechanism.

Tehan and Humphreys's (1998) third experiment showed a similar proportion of interference error in the standard condition (*M* = .07) compared to the present English experiment (*M* = .06), but a higher proportion of interference errors in the phonological interference condition (*M* = .18) than the one found in this English experiment (*M* = .09). One plausible explanation is that Tehan and Humphreys used foils formed by only three phonemes which were all repeated among the fillers of the second block (e.g., the foil was gull and the fillers were ghost, bun, and hell), but in the present English experiment only seven foils out of the eighteen foils of the experiment had three phonemes, while eleven foils were formed by four phonemes and, in the phonological condition, only three out of the four phonemes of the foil were repeated among the fillers of the second block (e.g., for the foil *collie*, that has four phonemes, only three phonemes were distributed among the fillers: kind, lost, sari). This was to equate the English experiment with the Chinese experiment. The characteristics of the Chinese language constrained the number of words formed by only three phonemes; most of the words used in the study were made of four phonemes (and two characters). The fact that the four phonemes were not repeated among the fillers of the second-block might have decreased the probability of PI in the phonological condition. Actually, Tehan and Humphreys's (1998) second experiment showed no phonological interference error when only one phoneme of the foil in the first block was repeated in a filler of the second block, indicating that the more phonemes of the foil are repeated, the higher the probability of interference error to occur.

Moreover, Tehan and Humphreys (1998) found a larger effect size (d = .89) in the difference between the standard and the phonological interference conditions compared to this English experiment (d = .31). This must be due to the larger proportion of interference error in the phonological condition of their experiment. In this sense, the fact that the Chinese and English experiments had a similar effect sizes (.25 and .31, respectively) might indicate that, in both experiments, obtaining a smaller proportion of interference error in the phonological condition—compared to Tehan and Humphreys's results—, may be due to the fact that by not employing all the phonemes of the four-phonemes foils among the fillers of the second block, may have consequently affected the value of the effect size in both experiments

The smaller proportion of interference error in the phonological condition found in the Chinese and English experiments—compared to Tehan and Humphreys's (1998) results—may not be related to the fact that in Experiment 1 written response was used for recall, whereas Tehan and Humphreys used spoken response for recall. The reason is that Goh and Tan (2006) used written recall, and Tehan and Humphreys used spoken recall, but all of them obtained similar interference error proportions. Both works studied PI effects employing filler words that rhymed with the foil, even though Goh and Tan inserted the rhyme in the first block of words and Tehan and Humphreys in the second block of words.

The present results showed that English-Mandarin bilinguals recoded both languages phonologically. However, this does not imply that phonological recoding was a prerequisite to access to meaning. It may be possible that meaning was accessed a priori and phonological recoding was carried out a posteriori. In this case, phonological recoding would be a memory strategy—by default probably—to maintain information presented serially. It could also be possible that the overall effect of phonological recoding was due to English dominant bilingual participants who processed information phonologically as monolingual studies (Tehan & Humphreys, 1995,1996,1998) carried out in English have shown. In this case language processing of the Chinese dominants would not be noticeable. The hypothesis was explored by investigating if Chinese proficiency affected the results.

In splitting the whole sample into two different groups of proficiency in Chinese (see Table 2.2), smaller groups were obtained in both the Chinese and the English experiments. Thus, the results for each group of Chinese proficiency were even more comparable to those obtained by Tehan and Humphreys's third experiment in which the sample size was 20.

The pattern of interference errors revealed by the planned comparisons was different for the more Chinese proficient group (group A), $t < 1$, $d = .14$, and the less Chinese proficient group (group B), $t(33) = 2.48$, $p < .01$, $d = .43$, in the Chinese experiment. This also appeared to be the case for the English experiment, group A: $t(37) = 1.38$, *ns,* $d = .22$, and group B: $t(23) = 2.06$, $p < .05$, $d = .42$. By splitting the sample into different groups according to proficiency in Chinese, the effect sizes for the less proficient group (group B) increased compared to the size effect for the whole sample (.43 and .42 compared to whole sample effect sizes .25 and .31, for the Chinese and English experiments, respectively). However, effect sizes for the less Chinese proficient group did not reach .89, the size effect reported by Tehan and Humphreys's (1998) third experiment with English monolinguals. As explained previously, it may be due to the fact that the present experiment did not repeat all the phonemes of the foils among the filler words of the second block of words. Of course, the possibility that English monolingual and English orientated English-Mandarin bilinguals codify phonological traces in STM differentially cannot be discarded.

The results showed that the more Chinese proficient group did not show more interference errors in the phonological condition than in the standard, whereas the less Chinese proficient group was sensitive to phonological interference. The results can be interpreted solely in terms of participants with less proficiency in Chinese seeming to apply a phonological strategy at reading and memorising both Chinese and English, possibly they are more dominant in English and recode information phonologically due to the influence of English, a language that is more phonetically based than Chinese.

If phonological recoding was not taking place in the more Chinese proficient group, was this group mainly relying on the visual characteristics of the characters in order to access meaning? There is a need to know if visual traces play a decisive role in Chinese language processing (Experiment 2). The literature on Chinese language processing has shown the importance of visual and spatial traits in word recognition and even memory (Flaherty, 1997; Chen & Juola, 1982; Tavassoli, 2002; Liu, 1997; Perfetti & Zhang, 1991; Hue & Erickson, 1988).

To summarise, the main results of Experiment 1 showed strong evidence that Chinese is phonologically recoded in this cued recall task but recoding seems to be only carried out by participants who do not have an excellent command of Chinese, indicating that maybe they are better in English and employ recoding—commonly used in alphabetic languages—to read Chinese. In contrast, participants who were excellent in Chinese did not show phonological interference probably due to a more integrated visual, phonetic and semantic codification as suggested by Sun's study (as cited in Chitiri et al., 1992). However, the criterion of academic proficiency alone may not be a good way to discern between participants stronger in Chinese and those stronger in English. This issue will also be addressed in Experiment 2.

CHAPTER 3

EXPERIMENT 2

Experiment 1 suggested that there could be differences in STM between English-Mandarin bilinguals with different proficiency in Chinese. Particularly, the more proficient group did not show phonological interference effects in recall, neither in Chinese or English, whereas the less proficient group did. The less proficient group, then, could be behaving as the English speaking participants of Tehan and Humphreys's (1998) experiments. It was suggested that the less proficient group could be formed by bilinguals dominant in English who codified the information in phonological code, as English monolinguals do. However, the design of Experiment 1 could not ascertain the type of memory codes for participants who pertained to the more Chinese proficient group. It was proposed that, since the more proficient group did not show phonological interference, it could be that their main memory traces were visual.

The main hypothesis of Experiment 2 states that English dominant participants will show phonological interference due to a greater phonological awareness and a more phonemic-based language processing. In contrast, Chinese dominant participants will show logographic interference because they rely on visual information at processing.

To test the hypothesis, the design of Experiment 1 was replicated with one additional condition: the visual interference condition (see Figure 3.1), in which the shape of the foil (e.g., 沙发) was repeated or distributed among the fillers (e.g., 秒表， 彭友，报废) of the second block. This time, the experiment was run only in Chinese because the objective was to find out the nature of memory traces of Chinese for bilinguals with dominance in either Chinese or English. Moreover, English does not allow a similar visual interference condition because it is not logographic.

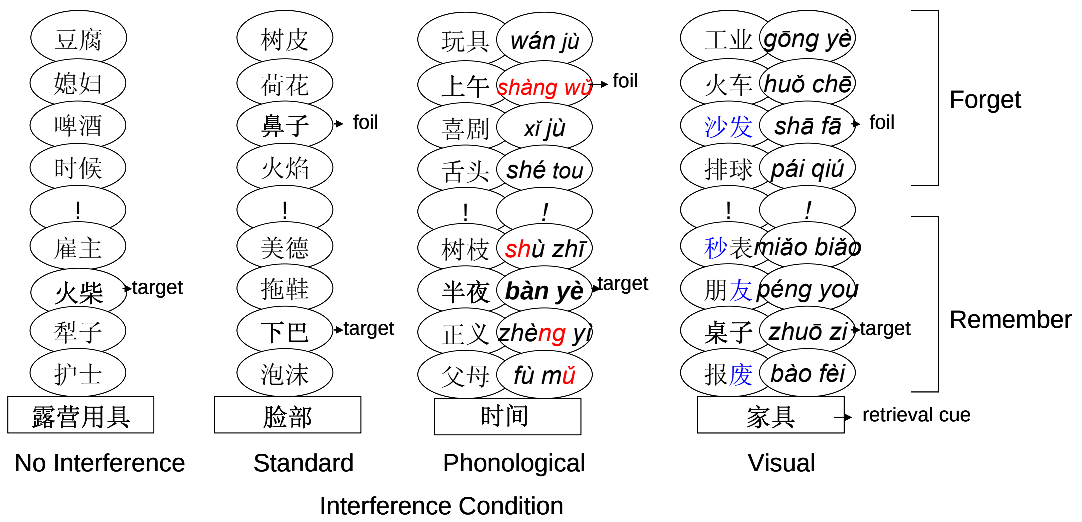

Figure 3.1. Experimental conditions in Experiment 2.

No interference condition. English translation from top to bottom: bean, daughter-in-law, beer, time, employer, matches (target), pear, nurse, item of camping equipment (cue).

Standard condition. English translation from top to bottom: bark, lotus, nose (foil), flame, morality, slippers, chin (target), foam, part of a face (cue).

Phonological condition. English translation from top to bottom: toy, morning (foil), comedy, tongue, branch, midnight (target), justice, parents, time of day (cue).

Visual condition. English translation from top to bottom: industry, train, sofa (foil), volleyball, stopwatch, friend, table (target), scrap, house furniture (cue).

Language dominance was measured with a language questionnaire and from the responses in the language questionnaire three groups of different language dominance were identified. The language questionnaire provided information on English and Chinese proficiency and also on language use. Self-evaluation is frequently used to assess bilingualism (Hamers & Blanc, 2000) and can provide useful information about language dominance. A measure of language use was important since it could be possible that some participants were English dominants but academically excellent in Chinese (despite not using Chinese at speaking, reading and writing).

After that, a LDT (word vs. nonword) was used as independent measure to test the validity of the dominance classification obtained from the language questionnaire.

Method

Participants

A sample of 86 English-Mandarin undergraduate students from the National University of Singapore, who did not participated in Experiment 1, took part in this experiment for course credit.

Design

The IV was interference condition and was run within subjects with four levels: no interference, standard interference, phonological interference and visual interference. Language dominance: Chinese, Mixed and English, was a subject variable. The dependent variable (DV) was response probability of interference errors.

Materials

Thirty-six foils, targets and cues were selected from the normative data for taxonomic categories collected by McEvoy and Nelson (1982) and translated into Chinese. Eighteen more categories were picked for one-block trials (see Table B1 in Appendix B). In the phonological condition, trials contained words made up of two characters. The first and last phoneme of the four-phoneme foils plus either the second or the third phoneme were repeated among the critical fillers of the second block. Trials composed by single character words were composed by three phonemes. For single character words, each phoneme of the foil was distributed among the critical fillers of the second block. In the visual condition, some filler words contained five phonemes given the difficulty of finding only four-phonemes words visually similar to the foils. In the visual condition, the characters employed for the critical filler words were visually similar to the foils but dissimilar in pronunciation. This was important to ensure that any effects could be attributed to logographic and not phonological similarity. The shape of the foils composed by two characters was distributed among the critical fillers of the second block. A similar-shape character to the first character of the two-character foil (e.g., 裤子) was used as a first character of the first two-character filler word (e.g., 祈祷) of the second block. The other critical filler words contained, in their second character (e.g., 美好, 储存), the same or a very similar-shape character to the second character of the foil (e.g., 裤子). The shape of single character foils (e.g., 方) was repeated or distributed among the critical filler words of the second block (e.g., 力, 边, 动).

Fifteen participants who did not participate in Experiment 2 ranked foil and target typicality (see Appendix B, Questionnaire B1). The fifteen participants also marked which words—those words employed later in the experiment—they were unable to read or did not know the meaning of. This was to ensure that words were familiar to participants. Only one filler word was unknown by thirteen of the fifteen participants (铝箔, aluminium foil) and it was not removed because it was neither a foil nor target word. Foils were selected from words mostly ranked as the first or second most typical instances, while targets occupied subsequent rankings. *T*-test confirmed that foils (M = .0062, SD = .0115) and targets (M = .0060, SD = .0112) were matched for word frequency (Wang et al., 1990), $t < 1$. *T*-test confirmed that foils (M =13.06, SD = 4.87) and targets (M =12.89, SD = 4.46) were also matched for number of strokes, $t < 1$. The proportion of phonetically transparent foils (.19) was the same than the proportion of phonetically transparent targets (.19).

As in Experiment 1, foils and targets occupied both the second or third position in the lists to avoid the primacy and recency effects. However, one-block trials contained targets inserted in any position of the list.

Four versions of the experiment were created in order to rotate the lists through the different experimental conditions across different participants. Table B1 and Table B2 in Appendix B show the critical words of Experiment 2.

The LDT comprised 50 words and 50 nonwords with two-compound characters and a total of four or five phonemes. Twenty-five of the nonwords were combination of two characters with no meaning (standard nonwords). To create the other 25 nonwords, two-character words were chosen and then each character changed by one homophonic character in a way that the sound of the word was correct but the characters employed were incorrect (special nonwords). An example of standard nonword is 表处 (biǎo chù), which has no meaning; and an example of special nonword is 完据 (wán jù) which has no meaning but sounds exactly like 玩具 (wán jù, toy). It was expected that English dominant bilinguals showed more difficulty at recognising special nonwords if phonological recoding was taking place during the lexical decision performance. Table B3 in Appendix B shows the list of stimuli employed in the LDT.

The language questionnaire (see Questionnaire B2 in Appendix B) comprised six questions that asked about the language they generally use to speak, read and write, and used a 9-point Likert-scale (1 *exclusively English,* 2 *mostly English but Chinese on rare occasions,* 3 *frequently English but sometimes Chinese,* 4 *slightly more English than Chinese,* 5 *both languages equally,* 6 *slightly more Chinese than English,* 7 *frequently Chinese but sometimes English,* 8 *mostly Chinese but English on rare occasions,* 9 *exclusively Chinese*). Participants also rated their proficiency at speaking, reading and writing Chinese (1 *very low,* 2 *low,* 3 *average,* 4 *high,* 5 *very high*). The questionnaire finished asking the participants about their academic scores in English and Chinese at O and AO levels (see Appendix B, Questionnaire B2).

Procedure

The procedure of the recall task was identical to Experiment 1 (Chinese version).

After completing the memory task, they performed a LDT. Participants were requested to respond as quickly and accurately as possible using appropriately labelled buttons, whether a compound-character was a word or a nonword. No feedback was provided to the subject. A “READY” sign (2000 ms) preceded each stimulus and participants had to response within 2000 ms of the onset of the stimulus. Participants practiced with six trials using words not in the LDT before starting the LDT. Stimuli were presented randomly and continuously. After the 50^{th} trial, they were allowed to rest if necessary. They filled up a brief questionnaire on language use and proficiency at the end of the session.

The whole experiment lasted approximately 50 minutes.

Results and Discussion

Data of four participants were discarded because they scored less than .32 proportion of correct responses (2 standard deviations) in one-block trials (M = .70, SD = .19). Two more participants were also discarded due to their bad performance in the LDT (only 5 correct rejection out of 50, and 2 hits out of 50). The data of 80 participants were used in the subsequent analyses.

In the cued recall experiment, partial correct responses in the visual experimental condition were scored as visual interference errors, since recalling part of the foil denoted that the physical traces of the foils were codified in memory. Partial correct response in the visual experimental condition represented 31% of the total of correct response for that experimental condition across all dominance groups.

Language Dominance Groups

To classify the participants into different language dominance groups, the critical responses of the language questionnaire (Questionnaire B2 in Appendix B) were correlated to each other with Spearman's *rho* (see Table 3.1)[9].

Table 3.1. Spearman's *rho* correlations between critical responses in the language dominance questionnaire (Experiment 2).

Academic Proficiency	Academic Proficiency (1: C…3: A)		Language Use (1: English…9: Chinese)			Subjective Proficiency (Chinese)		
(1: C…3: A)	Chinese	English	Speak	Read	Write	Speak	Read	Write
Chinese	-	- .16	**.46**	**.50**	**.43**	**.48**	**.57**	**.54**
English		-	**-.37**	-.20	-.01	**-.43**	-.18	-.17
Language Use (1: English…9: Chinese)								
Speak				**.67**	**.59**	**.68**	**.60**	**.47**
Read				-	**.65**	**.50**	**.72**	**.61**
Write					**-**	**.46**	**.57**	**.58**
Subjective Proficiency (Chinese)								
Speak						**-**	**.66**	**.53**
Read							**-**	**.78**
Write								**-**

Note. Correlation is significant at the 0.01 level (2-tailed). Coefficients in bold indicate significant correlation. Academic proficiency of Chinese corresponds to the results of Chinese language at AO levels, and academic proficiency in English corresponds to the results obtained in the General Paper at A levels. The numerical scores (1 for C5 and C6, 2 for B3 and B4, and 3 for A1 and A2) were used instead of the letter grades in order to obtain an ordinal scale.

Correlations were done to find which objective (academic proficiency) and subjective measures (English and Chinese language use, and subjective proficiency in Chinese) correlated, and, thus, be able to better discern with more data—and not only with academic proficiency—between Chinese and English dominants. Academic proficiency alone is not a good index of proficiency because some students can be academically excellent in Chinese but may not use the language and self-evaluation

[9] Spearman's *rho* was used because the academic grades and the scale for language use are measured at the ordinal level. Although the Likert-type scale used for the subjective proficiency ratings could be considered interval, a more conservative assumption was made so that the same statistic is used for all correlational measures.

measures of language use and proficiency are good predictors of the degree of bilingual competence (Hamers & Blanc, 2000). Hamers and Blanc (2000) recommended combining the information provided by the subject about his behaviour (measured in this study by the questionnaire) and objective measures. In this case, academic proficiency in Chinese (objective measure) and the responses of the questionnaire (subjective measure) were chosen together to classify the participants.

The correlations showed that scores in *Chinese at AO levels* correlated positively with the all the measures related to *use* of Chinese and *subjective proficiency* in Chinese. That is, the more academically proficient in Chinese, the more use of Chinese at speaking ($r = .46$), reading ($r = .50$), and writing ($r = .43$); and the more academically proficient in Chinese, the higher the ratings were for subjective proficiency at speaking ($r = .48$), reading ($r = .57$), and writing ($r = .54$) in Chinese. All the measures related to the *use* of Chinese and *subjective proficiency* in Chinese (speaking, reading, and writing) correlated significantly and positively among each other, indicating that the measures used to gauge the proficiency of Chinese were closely related to each other. Interestingly, the scores for English in the General Paper correlated negatively only with *use of Chinese at speaking* ($r = -.37$) and *subjective proficiency at speaking Chinese* ($r = -.43$), but not with the rest of the reading and writing measures. So, the better the participant is in English, the less he or she uses *Chinese at speaking* and the poorer will be his or her *subjective proficiency at speaking Chinese*. Academic proficiency in Chinese was not related to academic proficiency in English ($r = -.16$), indicating that the earlier speculation made in Experiment 1 that those with poorer scores in Chinese may be better in English is not supported. Hence, to determine language dominance, multiple criteria based on the pattern of correlations between academic performance, language use, and subjective proficiency was adopted. The reasons for using these critereria are as follows:

Academic proficiency in Chinese was related to *use* and *subjective proficiency* in Chinese. So, the *academic proficiency in Chinese* variable was chosen as one of the criteria to classify language dominance. In addition, since English academic proficiency was only negatively correlated with *Chinese use at speaking* and *subjective proficiency at speaking Chinese*, these two variables: *use of Chinese at speaking* and *subjective proficiency at speaking Chinese* were also chosen as two other criteria to classify language dominance. Infrequent use and less subjective proficiency in speaking Chinese suggest more dominance in English, and hence related to better academic English proficiency.

The three criteria were used *jointly* to determine language dominance (i.e., to be placed in one of the dominance groups all 3 criteria must be satisfied).

With regards to the Chinese academic proficiency, Chinese dominant participants must have scored A in Chinese at AO levels. English dominants must have scored less than A in AO levels. Among the 80 participants, 41 had scored an A in Chinese at AO levels.

The mean for the *Chinese use at speaking* in the 9-point scale was 4.36 (*SD* = 1.77) (which was between *slightly more English than Chinese* and *both languages equally*). No participant reported using mostly or exclusively Chinese. The fact that English is the language used at university led the students to use English a great part of their time. The criterion chosen was that Chinese dominants must rate at least 5 or higher on this scale, while English dominants must rate 4 or lower.

The mean for the *subjective proficiency at speaking Chinese* in the 5-point scale was 3.5 (*SD* = .97). The criterion chosen was that Chinese dominants must rate at least 4 or higher on this scale, while English dominants must rank 3 or lower.

Thus, Chinese dominants were those who scored A (A1 or A2) in Chinese at AO levels, *and* spoke Chinese and English at least equally often or more Chinese than English, *and* their subjective proficiency at speaking Chinese was high or very high. English dominants were those who scored less than A in Chinese at AO levels, *and* spoke more English than Chinese, *and* rated their proficiency in Chinese as average, low or very low. Mixed bilinguals were those who did not fit into the Chinese dominant and English dominant groups.

The different dominance groups were composed of: 24 Chinese dominant bilinguals, 30 Mixed, and 26 English dominant bilinguals. The size of each group was comparable to the size of the sample used by Tehan and Humphreys's (1998) third experiment (20 participants). Table 3.2 summarises the characteristics of the 3 groups.

Table 3.2. Characteristics of the 3 groups of language dominance (Experiment 2).

Language Dominance	Academic Proficiency in Chinese (1: C…3: A)			Speaking: Language Use (1: English…9: Chinese)			Speaking: Subjective Proficiency in Chinese (1: Very low…5: Very High)		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode
Chinese	3	3	3	6.04	6	6	4.25	4	4
Mixed	2.57	3	3	4.47	4	3	3.80	4	4
English	1.65	2	2	2.69	3	3	2.46	3	3

With regards to the Mixed dominant bilinguals, the modes of *use of Chinese at speaking*, *subjective proficiency in Chinese at speaking*, and the scores in Chinese at AO levels showed that most of them speak *frequently English but Chinese in rare* *occasions*, that they rate their proficiency at speaking Chinese mainly as *high,* and that their proficiency in Chinese is mainly A. So, they are academically good but they use more English than Chinese at speaking.

An independent test of the dominance classification

The classification of the dominance groups was tested using an independent LDT.

Table 3.3 shows the results of the LDT.

Table 3.3. LDT results for the 3 groups of language dominance.

Language Dominance	Response: Correct			Response: Error		
	Hit	Correct Rejection: Standard	Correct Rejection: Special	False Alarm	Miss	*d'*
Chinese	.94	.83	.84	.15	.06	2.72
	742.64	*1013.31*	*1009.88*	*1043.26*	*919.85*	
Mixed	.91	.79	.83	.16	.09	2.44
	726.29	*1025.24*	*1015.55*	*933.64*	*949.52*	
English	.87	.66	.70	.30	.13	1.68
	791.42	*1056.97*	*1029.65*	*999.32*	*1054.66*	

Note. Values in italics refer to RT.

If the dominance classifications were valid, Chinese dominant participants were expected to score more on hit and correct rejection (correct response), and less on false alarm and miss (error response), compared to the other two groups. Chinese dominants were also expected to be faster at responding correctly (hit and correct rejection) than the other two groups. In addition, Chinese dominants were expected to discriminate better between words and nonwords (*d*'). Moreover, if English dominant participants were using phonological recoding to access meaning, it could be that they showed particular difficulty in recognising special nonwords (more mistakes and longer RT) because the sound of special nonwords (e.g., 完据 /wán jù/), corresponded to a real words (玩具, /wán jù/, toy) but the graphic characters did not represent that meaning.

A one-way between-subjects ANOVA (Chinese dominants, Mixed, and English dominants) was performed on proportion of correct response (= [hit + correct rejection] / 2), on error response (= [false alarm + miss] / 2), on RT for correct response, on word/nonword discriminability (*d*'), on proportion of correct rejection of special nonwords, and on RT for correct rejection of special nonwords[10].

ANOVA showed that there were significant differences between groups for proportion of correct response (pooled hit and correct rejection proportions), $F(2,77) = 8.14$, $MSE = .04$, $p < .05$, $\eta^2 = .28$. All pairwise comparisons among means were tested using Bonferroni at $\alpha = .025$. English dominants ($M = .87$, $SD = .01$) made significantly fewer correct responses than the Mixed dominants ($M = .91$, $SD = .01$), $p < .001$, and the English dominants ($M = .77$, $SD = .09$) also made significantly fewer correct responses than the Chinese dominants ($M = .89$, $SD = .06$), $p < .001$. No significant differences were found between Chinese and Mixed dominants, $p > .025$, *ns*. No differences in RT for correct response were found between the three groups of dominance, $F < 1$.

ANOVA also showed that there were significant differences between groups for proportion of error response (pooled false alarm and miss proportions), $F(2,77) = 16.64$, $MSE = .09$, $p < .001$, $\eta^2 = .30$. All pairwise comparisons among means were tested using Bonferroni at $\alpha = .025$. English dominants ($M = .21$, $SD = .09$) made significantly more errors than the Mixed dominants ($M = .12$, $SD = .09$), $p < .001$, and

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[10] Separate analyses of hit and false alarm rates were not necessary as these two measures are subsumed in the *d'* analyses.

the English dominants ($M = .21$, $SD = .09$) also made significantly more errors than the Chinese dominants ($M = .10$, $SD = .06$), $p < .001$. No significant differences were found between Chinese and Mixed dominants, $p > .025$, *ns*.

Differences were also found in the measure of word/nonword discriminability (d'), $F(2,77) = 19.53$, $MSE = 7.35$, $p < .001$, $\eta^2 = .34$. All pairwise comparisons among means were tested using Bonferroni at $\alpha = .025$. English dominants discriminated between words and nonwords ($M = 1.68$, $SD = .57$) worse than Mixed dominants ($M = 2.44$, $SD = .68$), $p < .001$, and worse than Chinese dominants ($M = 2.72$, $SD = .55$), $p < .001$. No significant differences were found between Chinese and Mixed dominants, $p > .025$, *ns*.

Differences in the proportion of correct rejection of special nonwords were found, $F(2,77) = 8.18$, $MSE = .16$, $p < .001$. Pairwise comparisons, using Bonferroni at .025 level of significance, showed that English dominants ($M = .70$, $SD = .17$) made fewer correct responses compared to the Mixed dominants ($M = .83$, $SD = .13$) and compared to the Chinese dominants ($M = .84$, $SD = .11$), all *p*s < .025. However, no differences were found between Mixed dominants and Chinese dominants, $p > .025$, *ns*. No differences in RT for correct special nonword response were found for the three groups of language dominance, $F < 1$.

In summary, the LDT analyses consistently differentiated the English dominant group from the Mixed and Chinese dominant groups, providing some independent evidence of the differential level of language dominance among the groups. LDT performance could not differentiate between the Chinese dominant and Mixed dominant group. However, I continued to keep the Mixed dominant group separate from the Chinese dominant group in order to not dilute this category with the more diverse participants in the Mixed group. Since the LDT analyses showed no reliable differences between these groups, any subsequent differences between the Mixed group and the Chinese dominant group should be treated with caution.

Interference Errors Analyses

The main hypothesis of Experiment 2 stated that English dominant participants would show phonological interference due to a greater phonological awareness and a more phonemic-based language processing. In contrast, Chinese dominant participants would show orthographic interference because they rely on visual information at processing.

As in Experiment 1, the dependent variable (DV) was response probability of interference errors. The critical planned comparisons examined the difference in interference errors between the phonological and standard conditions, which would indicate the presence of phonological coding; and the difference between the visual and standard conditions, which would indicate the presence of visual coding. As in Experiment 1, separate analyses were done for the each group of language dominance.

Figure 3.2 shows the average of response probability of interference errors for each experimental condition by the three groups of language dominance.

As in Experiment 1, there were virtually no interference errors in the no interference conditions, Ms < .01, SDs < .04.

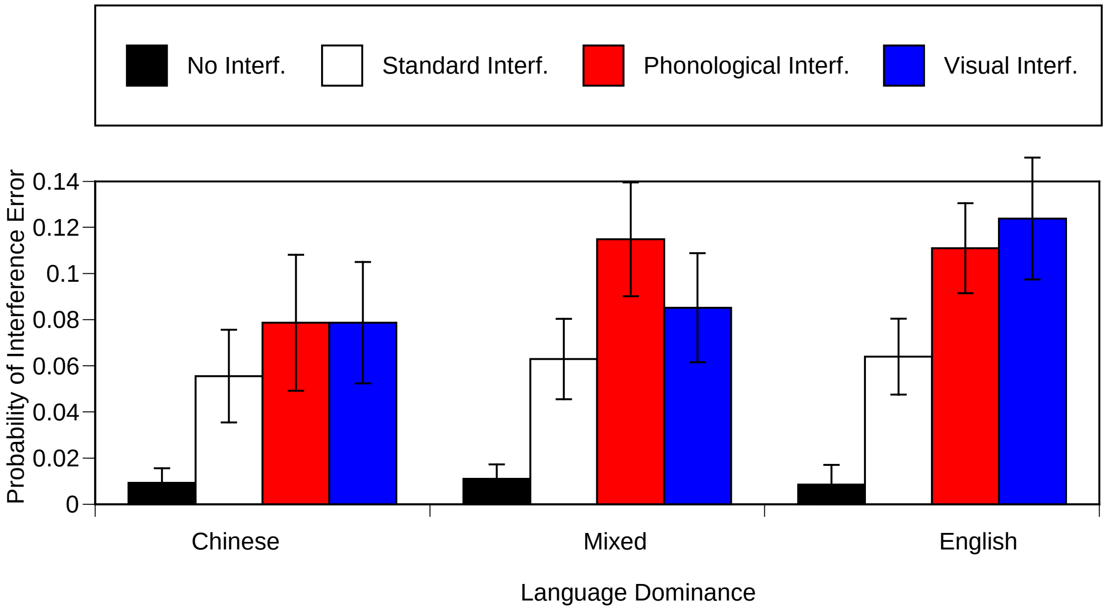

Figure 3.2. Average probability (+*SE*s) of interference errors by participants with different language dominance (Experiment 2).

Chinese dominants did not show significantly more interference error in the phonological condition ($M = .08$, $SD = .14$) than in the standard condition ($M = .06$, $SD = .10$), $t < 1$, $d = .17$. Moreover, Chinese dominants did not show significantly more interference error in the visual condition ($M = .08$, $SD = .13$) than in the standard condition ($M = .06$, $SD = .10$), $t(23) = 1.10$, *ns*, $d = .22$.

Mixed bilinguals made significantly more interference errors in the phonological condition ($M = .11$, $SD = .14$) than in the standard condition ($M = .06$, $SD = .10$), $t(29) = 2.63$, $p < .01$, $d = .48$. However, there were no significant differences between the visual condition ($M = .09$, $SD = .13$) and the standard condition ($M = .06$, $SD = .10$), $t(29) = 1.10$, *ns*, $d = .20$.

Finally, the English dominants made significantly more interference errors in the phonological condition ($M = .11$, $SD = .10$) than in the standard condition ($M = .06$, $SD = .08$), $t(25) = 2.19$, $p < .05$, $d = .43$. They also made significantly more interference errors in the visual condition (*M* = .12, *SD* = .13) than in the standard condition (*M* = .06, *SD* = .08), $t(25) = 3.20$, $p < .01$, $d = .63$.

Compared to Experiment 1, the effect sizes in Experiment 2 are slightly higher. This could be due to the fact that two trials of Experiment 1 were deleted in the analyses (see p. 40), decreasing the probability of interference error. However, the effect size for each group of language dominance of Experiment 2 did not reach the effect size between the standard and phonological conditions (.89) of Tehan and Humphreys's (1998) study. This may be due to the fact that, as in Experiment 1, not all the phonemes of the foil made by four phonemes were distributed among the filler words of the second block of words. Another possibility is that the phonological traces in STM are not codified by English-Mandarin bilinguals—even being English dominant bilinguals—the same way English monolinguals do.

The results of Experiment 2 replicated the findings of Experiment 1; particularly, that immediate memory seems to be strongly codified phonologically, but Chinese dominant subjects are immune to phonological PI. However, Chinese dominant bilinguals were not susceptible to visual interference as expected, but the English dominant bilinguals were susceptible to both phonological and visual interference.

The findings suggest that Chinese dominants might have a more integrated semantic, phonological, and visual STM since they show neither more phonological nor visual interference over and above semantic interference (measured in the standard condition). In contrast, English dominants may rely on phonological and visual information to codify and retrieve information from STM since they had significant phonological and visual interference over and above semantic interference. Moreover, the results of the English dominants replicated the studies carried out with monolingual samples (Tehan & Humphreys, 1998) showing that their dominance in English led them to recode phonologically and that those traces produced interference. In addition, they also showed visual interference, indicating that the visual traces played an important role in memory for Chinese. Reliance on the visual characteristics of the words have been demonstrated in second language (Harrington, 1992), suggesting that Chinese is being processed as a second language by the English dominants. Finally, Mixed dominants showed just phonological interference, like English monolinguals, showing that despite having, in general, an excellent proficiency in Chinese (the mode for academic results in Chinese at AO levels was A) they process language as English monolinguals do. The fact that they speak more English than Chinese (the mode for the language use at speaking was *frequently English but sometimes Chinese*) indicates that the use of English may be a critical variable related to phonological processing of Chinese. Moreover, Mixed dominants did not show visual interference indicating that Chinese is not processed as a second language, probably due to their excellent proficiency in Chinese. However, since the Mixed group was not as clearly defined as the Chinese and English groups, the interpretations must be considered with caution.

CHAPTER 4

GENERAL DISCUSSION AND CONCLUSION

This research sought to provide answers to the questions raised in the Introduction with regards to the extent to which phonological and visual codes influence the degree of semantic PI in a STM cued recall task for Chinese and English words. Moreover, special interest was put on the processing differences between bilinguals with different proficiency in Chinese.

Summary of Findings

One hypothesis predicted that a higher proportion of interference errors in the phonological condition (semantic interference plus phonological interference) compared to the standard condition (semantic interference only) would indicate that STM is greatly codified in phonological form and that the phonological traces are distributed to the level of phonemes. The hypothesis was tested in Experiment 1 with

Chinese words in one experiment and with English words in another experiment. The fact that Chinese is relatively a deeper and opaque language than English because logographs do not always represent the sound, the fact that Chinese does not promote phonological awareness at the phoneme level, and the fact that many studies found no phonological recoding for Chinese lexical access, made the Chinese experiment particularly interesting. The results indicated that even in Chinese, phonological traces are critical in STM codification since more interference errors were made under the phonological condition. However, another hypothesis predicted that phonological interference would be showed only by bilinguals whose proficiency in Chinese was not excellent, and maybe more dominant in English. This is because their greater experience with English could have led them to acquire greater phonological awareness making them process Chinese like English, phonologically, as the English monolingual studies have shown. The results supported the hypothesis, only the participants who were not excellent in Chinese (obtained B in Chinese at AO levels) showed phonological interference in the Chinese and the English experiments. The group more proficient in Chinese (those who obtained A in Chinese at AO levels) did not show more interference errors in the phonological than in the standard conditions in both the Chinese and English experiments.

In Experiment 2, I predicted more interference errors in the visual condition (semantic interference plus visual interference) than in the standard condition (semantic interference only) for those clearly dominant in Chinese because they might be accessing the words visually (since they did not show phonological interference in Experiment 1). I also predicted a higher proportion of interference errors in the phonological condition than in the standard condition for those clearly dominant in English due to a greater use of phonological recoding and greater level of phonological awareness. The results did not support the first hypothesis. Chinese dominants did not show significantly more visual interference errors than semantic errors. Furthermore, English dominants not only showed phonological interference but also showed visual interference. The Mixed group was formed by subjects who were academically very good in Chinese but spoke more English than Chinese, for that reason they were not considered Chinese dominants. This group showed only phonological interference but no visual interference.

Implications of the Findings

The Introduction also discussed about the relationship between STM and language as well as other cognitive processes. The literature review provided evidence that STM total capacity—or processing efficiency—plays an important role in vocabulary acquisition, language comprehension, reading, and so forth. Furthermore, it was described how a STM task—such as a cued recall task—could describe phonological and semantic processing; particularly, the experiments of Tehan and Humphreys (1995, 1996, 1998) provided evidence of phonological recoding and distributed phonological representations in memory.

Employing a similar design with English-Mandarin bilinguals and with English and Chinese words, the research questions—description of the phonological and visual codes in STM among bilinguals, and exploration of cognitive processing differences between bilinguals with different language dominance—were examined. The results suggested that dominance in one language led to processing the weaker language the way the stronger language was processed. Chinese language represents meaning better than sound. Yet English dominant and Mixed bilinguals recoded Chinese phonologically in order to access meaning. Besides, Chinese dominant adults did not recode English automatically, as was reported in word recognition and STM experiments carried out with alphabetic readers (Brysbaert, 2001; Marslen-Wilson, 1989; Baddeley, 1997; Tehan & Humphreys, 1998).

English is processed phonologically so Mixed and English dominant bilinguals seem to employ systematically a phonemic-based strategy when dealing with English and Chinese. The results match Everson's (1998) findings of strong correlation between pronunciation and identification of Chinese words by English speakers learning Chinese as a second language.

In a different type of experiment, Brandimonte and Gerbino (1993) found that once a drawing was given a name, mental transformations of the drawing were impeded. The same happened with the Chinese characters in the experiments, once the Mixed dominant participants engaged in verbal recoding, it may be speculated that they forgot the visual information (absence of visual interference). However, when participants cannot easily recode all the words phonologically, as happened with the English dominant participants dealing with Chinese, visual features of the stimuli are available and not substituted by phonological codes. To score the responses, those responses formed by one character of the foil and one character of the target, or a character of the foil plus an extra character, were considered visual interference errors. One example of a response formed by one character of the foil and one character of the target is one trial in which the cue was "FARM ANIMAL", the foil was *cow* (母牛) and the target *turkey* (火鸡), by combining the first character of the foil with the second character of the target, it can form the word *hen* (母鸡). Some participants recalled *hen,* a word that was not presented in the list. These interesting errors were prominent in the visual condition. This type of mistake was made mainly by English dominant participants, showing that they relied on visual features of the characters and tried to redintegrate the information from visual traces. Harrington (1992) cites many other experiments that show reliance on graphic cues in second language (like the Chinese language for the English dominants).

Chinese dominant bilinguals, on the other hand, accessed meaning directly. The practice of accessing meaning directly without recoding while dealing with Chinese might have induced them to use the same strategy in English. Chinese dominants did not show phonological and visual distributed memory probably because their phonological, visual and semantic processes are so integrated that they do not rely exclusively on the phonemic or the visual system to redintegrate the information from the traces left in memory. Indeed, Chinese dominant participants may have not recoded phonologically, not because they never use recoding, but because recoding provided no extra advantage to perform the cued task successfully.

Lau and Hoosain (1999) and Hue and Erikson (1988) found that their Chinese dominant participants seemed to recode phonologically in STM, at least for high frequency words. In contrast, the results of the experiments showed that Chinese dominants do not recode phonologically (they did not show phonological interference). The different results may be due to the characteristics of the tasks. Lau and Hoosain, and Hue and Erikson employed traditional memory span tasks, in which serial recall was requested. It might be that subverbal repetition, that requires phonological recoding, is the most appropriate strategy to maintain lists of numbers or words in the STM. Whereas, the cued recall task did not require serial recall, so phonological recoding would not have been necessary. The relationship between maintenance of serial order and phonological recoding suggest that both processes are subsumed by the same mechanism. English monolinguals, such those in Tehan and Humphreys (1998) experiments, and Mixed and English dominant bilinguals of the present experiments recoded Chinese words simply because their English dominance led them to recode written words automatically to access meaning.

It was expected that RTs in the Chinese LDT reflected language dominance. Amount of exposure to Chinese in general, and Chinese reading in particular, was expected to be related to automatisation of word and nonword recognition resulting in shorter RTs for the Chinese dominant group. However, the three groups of dominance showed no significant differences with respect to RT, although they showed differences in correct response. This striking result might be due to the fact that the words recognised correctly were common words accessed visually by all the participants, so no differences in RT could be appreciated. It could also be that phonological recoding does not necessarily require a longer time, especially for bilinguals who are in contact with the two languages constantly. In this case, lexical access would be achieved through parallel activation—and not sequential—of phonological and semantic information.

Relation to Chinese-English Differences

The literature on cognitive operations of Chinese usually confronts phonological processing versus visual processing. The importance of the visual traces in Chinese has been reviewed in the Introduction; however the tasks of the present experiments were not able to capture visual interference in those participants very proficient in Chinese. Yet it is possible that Chinese dominants accessed meaning through the visual characteristics of the word (without recoding phonologically). Visual interference would have not been observable because once meaning was accessed, the visual characteristics of the words would be inhibited or deactivated. In contrast, English dominants would distinguish between characters by visual hints and had to pay greater attention to the physical characteristics of the words. The visual effort as well as the weaker connection of the word to LTM due to less experience with Chinese (compared to the Chinese dominants that read and use Chinese more frequently) would lead English dominant bilinguals to retrieve the information by the visual traces left in the memory.

The experiments cannot however demonstrate whether the differences in STM are idiosyncratic to STM and independent from the differences found in lower levels of language processing (visual encoding, lexical access and phonological awareness), or differences in language processing found in higher levels (e.g., cue-based syntax, lexicality, semantic cues of animacy, etc.; Descovi & D'Amico, 2005). However, the study of language processing in STM is critical given the importance of STM in the human cognition architecture.

From the results obtained in the present study, it can speculated that the stronger language affected processing of the weaker language showing that humans tend to apply the strategies first learnt, or more practiced, on subsequent learning or performing. This would avoid extra cognitive effort (use diverse strategies at dealing with different languages), but it would stop the subjects to apply the most appropriate strategy to each language. It seems that the early use of two languages with different rules, pronunciations and orthographies, provide bilinguals—compared to monolinguals—with more mental flexibility, for example higher creativity and better reorganization of the information (Hamers & Blanc, 2000). So, in order to facilitate the use of different strategies while dealing with two languages, it could be recommended to teach different languages at a young age with the most appropriate pedagogic methods and this would increase cognitive flexibility. For example, it can be speculated that English dominant children could improve their competency in reading Chinese and use a strategy more focused on meaning if teachers emphasise to them how to access meaning. Massive reading and writing exposure, awareness of characters meanings, multiple examples of the same character inserted in different compound words, discriminate between similar characters, comprehension tests, and so on, could be appropriate tasks. On the other hand, for Chinese dominant children it would be recommended to promote phonological recoding and phonological awareness of Chinese and English since learning new alphabetic words depends on phonological ability (McBride-Chang et al., 2004; Jarrold et al., 2004; Baddeley, Papagno, & Vallar, 1988). Tasks that promote phonological abilities are: naming letters and objects, remembering spoken phrases, listening of songs and stories, repetition of unfamiliar sounds, and teaching phonics (Gathercole & Baddeley, 1993).

Relation to Memory Models

The results can be incorporated in Chappel and Humphreys's (1994) auto-associative neural network for sparse representations model. This connectionist model, created to study recognition and cued recall, conceives memory as associations represented by different patterns of connections in units and layers (phonological, semantic, context, etc.). In this model, retrieval is accomplished by redintegration of the traces left in those units. Cued recall proceeds by the intersection between the units activated by the cue and the units activated in memory. Interference occurs when the cue activates more diverse units corresponding to different words stored in memory. The results of the experiments showed that the foil's phonemes distributed among other words kept the foil active creating interference between the phoneme units corresponding to the foil word and the phoneme units corresponding to the target word. Moreover, English dominant subjects also showed that they were redintegrating information from physical parts of the compound-character words, suggesting that a word is kept in memory as single characters (or strokes). However, only those whose dominant language is alphabetic would store Chinese in phonemic form and in distributed phonemic units. The fact that Chinese dominants did not show phonological interference indicates that maybe Chinese is not codified and stored in memory at a phonemic level, it is also possible that the smaller phonemic unit is the syllable and not the phoneme. Nevertheless, this does not refute a connectionist model for Chinese memory. The existence of a composite memory and parallel access for Chinese visual traces, phonemes grouped in syllables and semantics is a possibility.

The results also fit in the WM model (Baddeley, 2000). Mixed bilinguals recode written information into phonological code automatically with the phonological loop. Since the phonological loop is also associated with retention of sequential information, phonological interference is irremediable. The phonological loop maintains all phonological traces of the list active and similar phonological traces would interfere with each other. English dominants also showed visual interference due to their reliance on the mechanisms of the visuospatial sketchpad, in which visual information is retained, whenever they could not recode phonologically due to their low proficiency in Chinese. The intrusion of words composed by parts of the foils or a combination between parts of the foil and parts of the targets show that visual memory has a very limited capacity (as Baddeley describes in his model), if all the strokes had been captured in the visual cache, recall would have been perfect; it also shows that English dominant participants are redintegrating from partial visual traces at retrieval. Chinese dominants would have a more efficient central executive system able to integrate information from the phonological loop, the visuospatial sketchpad and the LTM in the episodic buffer, and maybe the central executive would give more resources to the LTM in order to solve the task.

Any model, theory or description of bilingualism must take into account the different types of bilinguals. Therefore, it is important to note that it is not advisable to generalise these results to other type of bilinguals before taking into account the characteristics of the languages, the language proficiency and experience with the languages of the participants.

Limitations of the Study and Future Directions

Experiment 1 classified the language dominance of the participants by their academic proficiency in Chinese. It is acknowledged that this measure was dubious, since a participant could be very good in Chinese academically but not be Chinese dominant because of little use of the language. Experiment 2 collected data, through a questionnaire, on academic proficiency in Chinese and English, as well as Chinese and English language use, and subjective proficiency in Chinese with the aim of classifying language dominance with more measures and make the classification more valid. However, the questionnaire did not collect other important data such as age of acquisition or context of acquisition. Biographical data such as age of acquisition, for example, could have provided a measure of dominance since the age of acquisition is important not only in respect to cognitive representation but in other areas such as the linguistic, neuropsychological, cognitive and sociocultural development (Hamers & Blanc, 2000). Moreover, dominance classification could have been improved by collecting data about subjective proficiency at speaking, reading and writing in English, as well as age of acquisition of English. In Experiment 2, only English language use ratings and academic proficiency in English were collected.

Nevertheless, in Experiment 2, Chinese dominants and English dominants were clearly differentiated in terms of academic proficiency, subjective proficiency, use of Chinese at speaking, and proportion of correct and error responses, and discrimination between words and nonwords in a LDT. However, RTs in word recognition could not discern between these two groups. So, processing speed is not necessarily related to proficiency. This may be a limitation since dominance in Chinese is related to Chinese reading exposure and reading exposure is related to cognitive processing speed or automatisation (Chitiri et al., 1992). Furthermore, a third of the sample did not clearly pertain to either the Chinese dominant or the English dominant group, and they were labelled as Mixed dominants. Although Mixed dominants tend to be very good in Chinese but use mainly English at speaking, this group was not as homogeneous as the other two groups. Therefore, the interpretations regarding to the Mixed group must be taken with caution. Moreover, no objective measure (proportion of correct response and RT in the LDT) could differentiate between Chinese and Mixed dominants, but only the use of Chinese at speaking.

The test used to examine the validity of the dominance classification could also have been—and not only a LDT—a vocabulary test, for Chinese and English. Moreover, it could have been interesting to compare RT and response accuracy for English and Chinese words in order to test the differences between the two languages for each group of language dominance.

Another limitation is that although this study was designed to investigate phonological memory traces in STM for Chinese employing Tehan and Humphreys's (1998) experimental paradigm, there were two main differences between their design and the present one. The first is that the characteristics of Chinese did not allow finding many foils made by only three phonemes, so most of the words employed in the present study employed four phonemes, but only three phonemes were repeated among the fillers of the second block of words. This could have had affected the interference effect, decreasing the proportion of interference error. Another difference, compared to Tehan and Humphreys's experiment, is that Tehan and Humphreys requested spoken response, but the present experiment requested written response. It could be possible that requesting a spoken response led the participants to more phonological recoding than asking them to write their answer. However, Goh and Tan (2006), employing written response, found similar proportion of interference error to Tehan and Humphreys's.

The phonological transparency of the characters was measured a posteriori. The critical foils and targets were not chosen according to their transparency a priori. The proportion of transparent components in Chinese foils and targets was very small (.19 and .15 for Experiment 1, and .19 and .19 for Experiment 2, respectively) and a Latin-square counterbalancing procedure ensured that the critical words were rotated across conditions, so any efects of phonology transparency should be equated across all conditions. The fact that the group of foils and targets contained similar proportions of transparent characters, and the fact that the foils and targets were rotated across all the experimental conditions using a Latin-square procedure, assured that phonological transparency did not cause differences between the different experimental conditions.

In addition, an analysis of the type of phonological interference error among the less proficient in Chinese participants in Experiment 1, and the Mixed and English dominant participants in Experiment 2 was carried out to investigate whether the transparent foils (defined here as foils which contained phonetic components that predicted with no doubt the pronuntiation of the character or part of the complete foil word) were those which produced more phonological interference error compared to the nontransparent ones. For Experiment 1, the mean proportion of phonological interference error due to transparent foils was .15 (SD = .30), while the mean proportion of phonological interference error due to nontransparent foils was .85 (SD = .30). This difference was statistically reliable, $t(13) = 4.37$, $p < .05$. This means that phonetic transparency cannot be driving the phonological interference errors because there was proportionately fewer phonological interference errors due to transparent foils. For Experiment 2, the mean proportion of phonological error due to transparent foils was .07 (SD = .17), whereas the mean proportion of phonological interference error due to nontransparent foils was .93 (SD = .17), $t(32) = 14.34$, $p < .001$. That is, phonological interference errors were not, in these studies, induced by foils containing phonologically transparent characters.

However, it may be possible that English-Mandarin bilinguals process differently those characters that are completely opaque, those characters in which phonetic components cue the sound of the character, and those characters which phonetic components that predict the exact pronunciation of the character (transparent). The relationship between character transparency and word processing by different groups of language dominance in English-Mandarin bilinguals is a question open to further study.

Finally, it is important to bear in mind that a larger scope of the differences in language processing in bilinguals could have been achieved by including in the experiments bilinguals very strong in Chinese (Chinese from the Republic of China studying in Singapore), bilinguals very strong in English (English speakers learning Chinese in Singapore) and probably with monolinguals in China and in an English-only speaking country.

Conclusion

To conclude, different languages are processed differently and dominance in one language affects the way the other language is processed. Chinese dominants seem to use neither phonological nor visual strategies to memorise in a cued recall task. It is plausible that they access meaning directly. Mixed dominants, however, recode phonologically and store the information in phonological code. Their greater experience with English may have induced them to use phonological recoding as a strategy as demonstrated with alphabetic languages. The group less proficient in Chinese formed by English dominants showed visual and phonological interference, suggesting that they use recoding to process known words and visual memory to retain words they do not know how to pronounce or do not have time to recode into phonological form. Finally, distributed memory is evidenced in the pattern of interference (phonological and visual traces).

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APPENDICES

Appendix A

Materials for Experiment 1

Questionnaire A. Instances ranking and comprehension questionnaire.

TAXONOMIC CATEGORIES AND TYPICAL INSTANCES

Short-term Proactive Interference Task with Chinese Words
Social Work & Psychology
National University of Singapore

Name:		**e-mail:**	
Phone:		**Age:**	
Date today:		**Date of birth:**	
Languages that you can read:			
Grades in Chinese at O and A levels:	**O= A=**		**Subject No.**

Today I would like you to help me find out what things people commonly think of as belonging to various categories. The procedure will be as follows: You will read a category name (e.g. "extinct animal") and below of it different instances that could be included within this category (e.g. "dodo, dinosaur, triceratops, brontosaurus"). Then, you will have to rank the instances from the one you think is the most representative or typical of that category to the less. For example, if you think that "dinosaur" is the most representative you will put "1" next to it, if you think "dodo" would be the second most representative you would put "2" and so on.

The categories will be written in Mandarin. If you cannot read a word and/or you do not the meaning of a word, please tick off the box next to the word and ask the experimenter for the meaning and then continue ranking.

There are not correct and incorrect answers. Please answer as fast as possible according to your subjective thinking. If you have any question, please do not hesitate to ask the experimenter.

Be sure you rank all the instances and you do not put the same ranking to more than one instance. Thanks for your participation.

Example:

EXTINCT ANIMAL	**Rank**	**I can't read it**	**I don't know meaning**
Dodo	2		
Triceratops	4		X
Dinosaur	1		
Brontosaurus	3		

	rank	I can't read it	I don't know meaning
衣物			
服装			
夹克			
裤子			
帽子			
袜子			

	rank	I can't read it	I don't know meaning
冲凉房--装置			
厕所			
鏡子			
花洒			
龙头			
浴缸			

建筑材料			
钉			
钢			
块			
水泥			
砖			

颜色			
橙			
红			
蓝			
绿			
紫色			

方向			
东			
东北			
南			
西			
西北			

花园工具			
锄头			
耙子			
钳子			
软管			
铁锹			

形状			
圜			
立方			
球状			
五角			
筒			

露营用具			
背包			
灯笼			
火柴			
炉子			
靴子			

皇族成员			
公爵			
公主			
国王			
女王			
太子			

乐器			
低音			
钢琴			
吉他			
竖琴			

五官	rank	I can't read it	I don't know meaning
鼻子			
口			
下巴			
眼睛			
嘴唇			

牲口	rank	I can't read it	I don't know meaning
火鸡			
鸡			
马			
母牛			
猪			

布料	rank	I can't read it	I don't know meaning
棉			
绒			
丝绸			
羊毛			

花类	rank	I can't read it	I don't know meaning
百合			
雏菊			
玫瑰			
牡丹			

畜牲	rank	I can't read it	I don't know meaning
豹子			
狼			
老虎			
狮子			
熊			

水果类	rank	I can't read it	I don't know meaning
橙			
梨子			
苹			
葡萄			
樱			

肉类	rank	I can't read it	I don't know meaning
火腿			
牛排			
牛肉			
小羊			
猪肉			

啮齿动物	rank	I can't read it	I don't know meaning
蝙蝠			
仓鼠			
老鼠			
松鼠			
兔子			

车类	rank	I can't read it	I don't know meaning
巴士			
货车			
跑车			

四季	rank	I can't read it	I don't know meaning
春			
冬			
秋			
夏			

化学元素	rank	I can't read it	I don't know meaning
氮气			
黄金			
氢			
水银			
氧气			

能源	rank	I can't read it	I don't know meaning
电			
风			
煤			
热力			
太阳			

	rank	I can't read it	I don't know meaning
蔬菜类			
白菜			
胡椒			
黄瓜			
芹菜			
豌豆			
时间			
半夜			
上午			
晚上			
下午			
中午			
调味料			
参			
蒜			
香菜			
大自然			
海洋			
山			
峡谷			
岩石			

	rank	I can't read it	I don't know meaning
亲属			
表妹			
姑夫			
奶奶			
侄子			
祖母			
武器			
刀			
剑			
抢			
首饰			
戒指			
手表			
手镯			
项炼			
水路管道			
大海			
海湾			
海洋			
湖			
运河			

Please **proceed to the second part** of the session in the following pages.

Should you not be able to Read the word please place an X in the R box next to the word. Should you not be able to understand the Meaning please place an X in the M box next to the word. You may place an X in both R and M boxes should you not be able to read and understand the word.

		R	M		R	M		R	M		R	M		R	M		R	M		R	M		R	M
衣物	树枝			海味			奇迹			母鸡			老师			夹克			癌症			朋友		
冲凉房--装置	飞机			银色			柜子			正义			美德			皮革			浴缸			许多		
建筑材料	冰			床			店			三			饭			钉			工			人		
颜色	年			身			童			象			胖			脸			青			梦		
方向	忙			眠			虫			田			饼			东			轮			孙		
花园工具	日蚀			交流			智力			小麦			荔枝			爸爸			耙子			地图		
形状	千			慢			零			更			柑			筒			根			横		
露营用具	豆腐			午餐			啤酒			时候			老鹰			屋子			火柴			护士		
皇族成员	木材			玻璃			哥哥			蜡烛			高度			太子			蘑菇			疙瘩		
乐器	扣子			奶奶			茶壶			组织			桃子			肥皂			低音			季节		
五官	瀑布			鼻子			狐狸			十四			骨头			下巴			葡萄			妈妈		
牲口	树皮			石灰			母牛			内裤			婆婆			道德			火鸡			不大		
布料	狼			棉			山			颈			诚			绒			枕			巾		
花类	叔叔			师傅			雏菊			地址			国籍			谷类			百合			瓷器		
畜牲	维护			老虎			拖鞋			火焰			果树			豹子			事故			父母		
水果类	空			形			苹			战			捐			暂			橙			瞳		
肉类	美元			猪肉			白痴			报纸			帽子			火腿			妹妹			拜拜		
啮齿动物	杯子			害羞			老鼠			沙发			祖母			宝贵			兔子			定义		
车类	演出			跑车			黑色			火炬			自私			巴士			歌剧			雇主		
四季	星			冷			春			单			汗			圈			冬			疯		
化学元素	大哥			氧气			鹈鹕			袋子			演奏			水银			赢得			杂志		
能源	亮			叮			电			品			党			念			风			金		
蔬菜类	儿子			胡椒			结束			合法			和气			白菜			科技			勾销		

		R	M		R	M		R	M		R	M		R	M		R	M		R	M		R	M
亲属	态度			天鹅			表妹			毛衣			白色			小丑			祖母			国内		
时间	打扫			中午			含义			筷子			侄子			半夜			长椅			家属		
武器	看			贫			抢			醒			晨			控			剑			凭		
调味料	动			参			黄			宾			上			蒜			饼			村		
首饰	外出			土豆			戒指			日出			家具			卸货			手表			车子		
大自然	玩具			岩石			喜剧			滋味			羊毛			峡谷			歌手			积极		
水路管道	竹子			消息			运河			媳妇			浴巾			按摩			大海			贝壳		
鸟类	裤子												秃鹰			支出			拖鞋			卧房		
餐具	厕所												教室			叉子			蚊子			海洋		
宝石	砖												暖			生			双			钻		
坟地	蓝												墓地			学校			耳朵			下塌		
木匠工具	南												微笑			陶瓷			锯开			奶酪		
罪案	锄头												辣椒			狮子			绿色			谋杀		
消防局器材	圜												梯子			老是			荷花			薄弱		
家具	背包												到来			桌子			大小			基础		
厨房用具	国王												王国			老家			危机			炉子		
金属	吉他												钢			唱			方			聋		
鱼类													运气			大致			金鱼			未来		
鞋类													舌头			茶叶			咖啡			靴子		
宠物	泪			狗			日			秒			刀			龟			六			河		
传达讯息													绅士			水泥			电话			水槽		
建筑类													教堂			成长			木材			荣誉		
办公室具	葬礼			玫瑰			电脑			十六			十五			奴性			椅子			链条		

Table A1. Cues, foils, targets and critical fillers in the phonological experimental condition of Experiment 1 (Chinese).

					Critical Fillers					
Cue	Foil		Target		1		2		3	
衣物 *ARTICLE OF CLOTHING*	裤子 *kù zi*	*pants*	夹克 *jiā kè*	*jacket*	咖啡 *kā fēi*	*coffee*	护士 *hù shi*	*nurse*	儿子 *ér zi*	*son*
冲凉房--装置 *BATHROOM FIXTURE*	厕所 *cè suǒ*	*toilet*	浴缸 *yù gāng*	*bathtub*	自私 *cí qì*	*porcelain*	十四 *shí sì*	*fourteen*	耳朵 *ěr duǒ*	*ear*
布料 *TYPE OF CLOTH*	丝绸 *sī chóu*	*silk*	羊毛 *yáng máo*	*wool*	赛马 *sài mǎ*	*race(horse)*	滋味 *zī wèi*	*taste*	舌头 *shé tou*	*tongue*
颜色 *COLOUR*	红 *hóng*	*red*	青 *qīng*	*green*	横 *héng*	*horizontal*	童 *tóng*	*child*	梦 *mèng*	*dream*
方向 *COMPASS DIRECTION*	东 *dōng*	*east*	南 *nán*	*south*	店 *diàn*	*shop*	空 *kōng*	*empty*	凭 *píng*	*to rely on*
家具 *LIVING ROOM FURNITURE*	沙发 *shā fā*	*sofa*	桌子 *zhuō zi*	*table*	事故 *shì gù*	*accident*	豆腐 *dòu fu*	*bean*	吉他 *jī tā*	*guitar*
形状 *GEOMETRIC SHAPE*	圆 *yuán*	*circle*	筒 *tǒng*	*cylinder*	远 *yuǎn*	*far*	忙 *máng*	*busy*	根 *gēn*	*root*
露营用具 *ITEM OF CAMPING EQUIPMENT*	背包 *bēi báo*	*backpack*	火柴 *huǒ chái*	*matches*	薄弱 *bó ruò*	*weak*	瀑布 *pù bù*	*waterfall*	打扫 *dǎ sǎo*	*to clean*
皇族成员 *MEMBER OF ROYALTY*	国王 *guó wáng*	*king*	太子 *tài zi*	*prince*	高度 *gāo dù*	*height*	火焰 *huǒ yàn*	*flame*	癌症 *ái zhèng*	*cancer*

五官 *PART OF A FACE*	鼻子 *bí zi*	*nose*	下巴 *xià bā*	*chin*	拜拜 *bāi bāi*	*bye bye*	媳妇 *xí fù*	*daughterinlaw*	帽子 *mào zi*	*cap*
牲口 *FARM ANIMAL*	母牛 *mǔ niú*	*cow*	火鸡 *huǒ jī*	*turkey*	妹妹 *mèi mèi*	*younger sister*	奶奶 *nǎi nai*	*grandmother*	交流 *jiāo liú*	*ppl.exchange*
建筑材料 *BUILDING MATERIAL*	砖 *zhuān*	*brick*	钉 *dīng*	*nail*	枕 *zhěn*	*pillow*	圈 *qūan*	*ring*	念 *niàn*	*read aloud*
花类 *TYPE OF FLOWER*	玫瑰 *méi guī*	*rose*	百合 *bǎi hé*	*lily*	妈妈 *mā ma*	*mother*	维护 *wéi hù*	*protect*	石灰 *shí huī*	*lime*
畜牲 *WILD ANIMAL*	老虎 *lǎo hǔ*	*tiger*	豹子 *bào zi*	*leopard*	绿色 *lǜ sè*	*green*	荷花 *hé huā*	*lotus*	雇主 *gù zhǔ*	*employer*
水果类 *TYPE OF FRUIT*	苹 *píng*	*apple*	橙 *chéng*	*orange*	品 *pǐn*	*goods*	零 *líng*	*zero*	工 *gōng*	*work*
肉类 *TYPE OF MEAT*	猪肉 *zhū ròu*	*pork*	火腿 *huǒ tuǐ*	*ham*	智力 *zhì lì*	*intellect*	叔叔 *shū shu*	*uncle*	演奏 *yǎn zòu*	*play instr.*
啮齿动物 *TYPE OF RODENT*	老鼠 *lǎo shǔ*	*mouse*	兔子 *tù zi*	*rabbit*	辣椒 *là jiāo*	*chili*	歌手 *gē shǒu*	*singer*	基础 *jī chǔ*	*base*
车类 *TYPE OF VEHICLE*	跑车 *pǎo chē*	*sport car*	巴士 *bā shì*	*bus*	啤酒 *pí jiǔ*	*beer*	宝贵 *bǎo guì*	*precious*	大哥 *dà gē*	*eldest brother*
四季 *SEASON OF THE YEAR*	春 *chūn*	*spring*	冬 *dōng*	*winter*	诚 *chéng*	*honest*	孙 *sūn*	*grandson*	枕 *zhěn*	*pillow*
化学元素 *CHEMICAL ELEMENT*	氧气 *yǎng qì*	*oxygen*	水银 *shuǐ yín*	*mercury*	演奏 *yǎn zòu*	*play instr.*	赢得 *yíng dé*	*win*	杂志 *zá zhì*	*magazine*
能源 *SOURCE OF ENERGY*	电 *diàn*	*electricity*	风 *fēng*	*wind*	党 *dǎng*	*party*	念 *niàn*	*read aloud*	金 *jīn*	*gold*

蔬菜类 *GREEN VEGETABLE*	白菜 *bái cài*	*cabbage*	胡椒 *hú jiāo*	*pepper*	爸爸 *bā ba*	*father*	午餐 *wǔ cān*	*lunch*	小麦 *xiǎo mài*	*wheat*
亲属 *TYPE OF RELATIVE*	祖母 *zǔ mǔ*	*grandmother*	表妹 *biǎo mèi*	*cousin*	滋味 *zī wèi*	*taste*	葡萄 *pú tao*	*grape*	峡谷 *xiá gǔ*	*canyon*
时间 *TIME OF DAY*	上午 *shàng wǔ*	*morning*	半夜 *bàn yè*	*midnight*	树枝 *shù zhī*	*branch*	正义 *zhèng yì*	*justice*	父母 *fù mǔ*	*parents*
武器 *WEAPON*	枪 *qiāng*	*gun*	剑 *jiàn*	*sword*	圈 *qūan*	*ring*	千 *qiān*	*thousand*	凭 *píng*	*to rely on*
首饰 *PIECE OF JEWELRY*	戒指 *jiè zhi*	*ring*	手表 *shǒu biǎo*	*watch*	家具 *jiā jù*	*furniture*	大致 *dà zhì*	*approximately*	车子 *chē zi*	*car*
大自然 *NATURAL EARTH FORMATION*	海洋 *hǎi yáng*	*ocean*	岩石 *yán shí*	*rock*	和气 *hé qi*	*polite*	奶奶 *nǎi nai*	*grandmother*	癌症 *ái zhèng*	*cancer*
鸟类 *BIRD OF PREY*			老鹰 *lǎo yīng*	*eagle*						
餐具 *EATING UTENSIL*			叉子 *chā zi*	*fork*						
宝石 *PRECIOUS GEM*			钻 *zuàn*	*diamond*						
坟地 *BURIAL PLACE*			墓地 *mù dì*	*cemetery*						
木匠工具 *CARPENTER'S TOOL*			锯开 *jū kāi*	*saw*						
罪案 *CRIME*			谋杀 *móu shā*	*murder*						

消防局器材 *PIECE OF FIREFIGHTING EQUIPMENT*	梯子 *tī zi*	*ladder*
厨房用具 *KITCHEN APPLIANCE*	炉子 *lú zi*	*stove*
金属 *TYPE OF METAL*	钢 *gāng*	*steel*
鱼类 *TROPICAL FISH*	金鱼 *jīn yú*	*goldfish*

Note. The last ten cues, with no foil, pertain to the categories used for one-block trials.

Table A2. Cues, foils, targets and critical fillers in the phonological experimental condition of Experiment 1 (English).

			Critical Fillers		
Cue	Foil	Target	1	2	3
COMESTIC	blush	cream	box	plot	clash
PART OF A BOAT	mast	bridge	monk	dusk	hunt
DAIRY PRODUCT	milk	yogurt	mend	fist	cheek
TYPE OF DANCE	waltz	boogie	witch	gold	dress
BREED OF DOG	collie	hound	kind	lost	sari
EMOTION	anger	pity	ankle	digs	after
PIECE OF HORSE RIDING EQUIPMENT	rein	whip	rat	beige	learn
TOY	doll	car	dove	gosh	gull
PROFESSION	nurse	judge	knob	burn	sauce
RELIGIOUS ARTICLE	cross	icon	carry	prowl	swiss
SPICE	chilli	Clove	chess	fold	sufi
PART OF A TREE	bark	root	big	dark	jerk
WATER BIRD	swan	stork	salt	dwell	blown
TYPE OF WATERWAY	river	gulf	rely	envy	meter
KIND OF WOOD	pine	cedar	pig	mice	gown
WRITING IMPLEMENT	pen	ink	pace	beg	sun
CIRCUS ACT	clown	dogs	kiwi	bleed	ocean
TYPE OF FOOTWEAR	boots	clog	band	suit	glass
TYPE OF CANDY		gum			
TYPE OF SHIP		yacht			
TWO WHEELED VEHICLE		bike			
KIND OF LIQUOR		rum			
EXTINT ANIMAL		dodo			
HERB		mint			
UNIT OF LENGTH		foot			

CITRUS FRUIT	lime
TYPE OF BREAD	pita
ROOM IN A HOUSE	attic

Note. The last ten cues, with no foil, pertain to the categories used for one-block trials.

Appendix B

Materials for Experiment 2

Questionnaire B1. Instances ranking and comprehension questionnaire.

TAXONOMIC CATEGORIES AND TYPICAL INSTANCES

Short-term Proactive Interference Task with Chinese Words
Social Work & Psychology
National University of Singapore

Name:	**e-mail:**
Phone:	**Age:**
Date today:	**Date of birth:**
Languages that you can read:	
Grades in Chinese at O and A levels: O= A=	**Subject No.**

Today I would like you to help me find out what things people commonly think of as belonging to various categories. The procedure will be as follows: You will read a category name (e.g. "extinct animal") and below of it different instances that could be included within this category (e.g. "dodo, dinosaur, triceratops, brontosaurus"). Then, you will have to rank the instances from the one you think is the most representative or typical of that category to the less. For example, if you think that "dinosaur" is the most representative you will put "1" next to it, if you think "dodo" would be the second most representative you would put "2" and so on.

The categories will be written in Mandarin. If you cannot read a word and/or you do not the meaning of a word, please tick off the box next to the word and ask the experimenter for the meaning and then continue ranking.

There are not correct and incorrect answers. Please answer as fast as possible according to your subjective thinking. If you have any question, please do not hesitate to ask the experimenter.

Be sure you rank all the instances and you do not put the same ranking to more than one instance. Thanks for your participation.

Example:

EXTINCT ANIMAL	**Rank**	**I can't read it**	**I don't know meaning**
Dodo	2		
Triceratops	4		X
Dinosaur	1		
Brontosaurus	3		

情绪	rank	I can't read it	I don't know meaning
忧愁			
愤怒			
恐惧			
憎恨			
妒忌			

车类	rank	I can't read it	I don't know meaning
跑车			
巴士			
客车			
滑板			
敞篷货车			

颜色			
红			
棕色			
青			
橙色			
黄色			

花类			
玫瑰			
康乃馨			
雏菊			
百合			
郁金香			

时间			
上午			
破晓			
晚上			
中午			
半夜			

职业			
医生			
工程师			
律师			
护士			
作者			

水果类			
苹			
香蕉			
橙			
桃子			
梨子			

房子-房间种类			
卧室			
地窖			
浴室			
厨房			
客厅			

衣物	rank	I can't read it	I don't know meaning
裤子			
衬衫			
服装			
夹克			
袜子			

四季	rank	I can't read it	I don't know meaning
圣诞节			
秋			
春			
夏			
冬			

露营用具			
背包			
灯笼			
火柴			
睡袋			
炉子			

脸部			
鼻子			
下巴			
眼睛			
嘴唇			
口			

大自然			
峡谷			
小山坡			
海洋			
岩石			
火山			

建筑			
房屋			
公寓			
体育馆			
医院			
办公室			

形状			
方			
圆			
六方			
八方			
四方			

建筑材料			
砖			
块			
水泥			
混凝土			
钉			

马戏团-角色	rank	I can't read it	I don't know meaning
小丑			
杂技			
走钢索			
玩杂耍			
吊架			

武器	rank	I can't read it	I don't know meaning
抢			
刀			
来福枪			
矛			
剑			

布料			
丝绸			
牛仔布			
尼龙			
绒			
羊毛			

家具			
沙发			
椅子			
灯			
凳子			
桌子			

肉类			
火腿			
小羊			
猪肉			
肋骨			
牛排			

农业牲口			
母牛			
鸡			
马			
猪			
火鸡			

运动种类			
足球			
棒球			
篮球			
游泳			
网球			

啮齿动物			
老鼠			
蝙蝠			
仓鼠			
兔子			
松鼠			

亲属

	rank	***I can't read it***	***I don't know meaning***
表妹			
哥哥			
祖母			
母亲			
舅舅			

方向

	rank	***I can't read it***	***I don't know meaning***
南			
东			
东北			
西北			
西			

罪案

谋杀			
持械打抢			
绑架			
强奸			
偷窃			

能源

电			
煤			
热力			
核能			
风			

水上飞禽

鸭子			
火鹤			
鹈鹕			
海鸥			
天鹅			

皇族成员

国王			
公爵			
太子			
公主			
女王			

树身

树枝			
树皮			
叶子			
粗枝			
根			

冲凉房--装置

厕所			
浴缸			
龙头			
鏡子			
花洒			

化学元素

	rank	*I can't read it*	*I don't know meaning*
一氧化碳			
铁			
水银			
氧气			
锌			

畜牲

	rank	*I can't read it*	*I don't know meaning*
老虎			
熊			
狐狸			
豹子			
狼			

首饰

戒指			
手镯			
珥			
项炼			
手表			

木匠工具

锯开			
刀			
刨子			
尺子			
螺丝刀			

Please **<u>proceed to the second part</u>** of the session in the following pages.

Should you not be able to Read the word please place an X in the "I can't read it" box next to the word. Should you not be able to understand the Meaning please place an X in the " I don't know meaning" box next to the word. You may place an X in both "I can't read it" and " I don't know meaning" should you not be able to read and understand the word.

	I can't read it	*I don't know meaning*
情绪		
颜色		
时间		
水果类		
衣物		
露营用具		
车类		
花类		
职业		
房子-房间种类		
四季		
脸部		
大自然		
形状		
马戏团-角色		
布料		
肉类		
运动种类		
建筑		
建筑材料		
武器		
家具		
农业牲口		
啮齿动物		
亲属		
罪案		
水上飞禽		
树身		
化学元素		
首饰		
方向		
能源		
皇族成员		

	I can't read it	*I don't know meaning*
冲凉房--装置		
畜牲		
木匠工具		
鸟类		
餐具		
坟地		
厨房用具		
鱼类		
美国-货币		
金属		
乳制品		
正食		
菜类		
酸性水果		
酒类		
花生类		
乐器		
时间单位		
玩具		
消防局器材		
昆虫		
宠物		
交谈工具		
宗教场所		
办公室 器具		
背包		
鼻子		
厕所		
春		
电		
东		
方		
房屋		

	I can't read it	I don't know meaning
国王		
海洋		
红		
戒指		
锯开		
裤子		
老虎		
老鼠		
玫瑰		
谋杀		
母牛		
跑车		
苹		
枪		
沙发		
上午		
树枝		
丝绸		
卧室		
小丑		
鸭子		
氧气		
医生		
忧愁		
猪肉		
砖		
祖母		
足球		
巴士		
百合		
半夜		
豹子		
表妹		

	I can't read it	I don't know meaning
橙		
尺子		
地窖		
钉		
冬		
妒忌		
风		
钢		
火柴		
火鸡		
火腿		
吉他		
夹克		
剑		
金鱼		
老鹰		
栗子		
炉子		
萝卜		
美元		
墓地		
南		
年		
牛奶		
啤酒		
气球		
青		
石灰		
手表		
水银		
太子		
梯子		
天鹅		

	I can't read it	*I don't know meaning*
叉子		
兔子		
蚊子		
午餐		
下巴		
岩石		
羊毛		
叶子		
医院		
游泳		
浴缸		
圆		
杂技		
桌子		
作者		
成长		
刀		
电话		
电脑		
龟		
河		
教堂		
日本		
日		
荣誉		
泪		
链条		
六		
秒		
女性		
绅士		
十六		
椅子		

	I can't read it	*I don't know meaning*
偷窃		
水泥		
葬礼		
坠毁		
狗		
按钮		
按摩		
爸爸		
把手		
拜拜		
白痴		
白酒		
白色		
半		
板		
伴侣		
邦		
报废		
暴力		
保姆		
报纸		
悲剧		
贝壳		
备注		
庇护		
比赛		
必需		
边		
表扬		
表侄		
别处		
兵		
冰冻		

	I can't read it	I don't know meaning
桃子		
水槽		
补救		
补贴		
不朽		
不再		
不足		
猜想		
舱		
草莓		
茶壶		
肠		
长		
唱		
长椅		
朝代		
潮流		
车子		
成为		
赤道		
耻辱		
虫		
抽屉		
储存		
出发		
处决		
厨师		
床		
疮		
瓷器		
粗鲁		
粗俗		
摧毁		

	I can't read it	I don't know meaning
菠菜		
薄弱		
大厦		
大使		
大致		
大海		
代替		
歹徒		
带子		
单		
党		
到来		
缔结		
地址		
店		
电流		
定额		
定义		
丢失		
动物		
东西		
动		
赌博		
肚子		
对了		
夺得		
耳朵		
耳环		
发财		
发扬		
飞机		
肥皂		
粉		

	I can't read it	*I don't know meaning*
村		
大哥		
大陆		
父母		
复杂		
腐败		
葬礼		
高度		
高烧		
哥哥		
歌剧		
根		
更		
工		
公斤		
工业		
公寓		
孤独		
谷类		
骨头		
固执		
雇主		
关于		
柜子		
国籍		
果树		
国内		
海军		
罕		
含义		
豪华		
合法		
荷花		

	I can't read it	*I don't know meaning*
夫妇		
符号		
俘虏		
蝴蝶		
狐狸		
呼吸		
花朵		
怀孕		
混淆		
火车		
火焰		
嫉妒		
机器		
肌肉		
基于		
季节		
甲虫		
价格		
家具		
焦急		
教室		
交易		
接纳		
结束		
结尾		
街道		
紧		
金		
舅舅		
九月		
局部		
拒绝		
距离		

	I can't read it	*I don't know meaning*
和气		
合作		
黑色		
横		
课本		
砍		
肯定		
空		
扣子		
垮		
筷子		
辣椒		
蜡烛		
老家		
牢牢		
老是		
老师		
乐趣		
雷达		
肋骨		
冷		
力		
厉害		
梨子		
连		
脸		
亮		
猎人		
聋		
铝箔		
轮		
妈妈		
帽子		

	I can't read it	*I don't know meaning*
局势		
捐		
咖啡		
开始		
秘密		
秒表		
民		
木材		
母鸡		
男		
内地		
念		
奴隶		
暖		
排球		
盘		
判决		
胖		
泡沫		
碰		
朋友		
皮带		
品		
凭		
评		
凭		
瀑布		
祈祷		
奇迹		
歧视		
千		
勤		
球拍		

	I can't read it	I don't know meaning
美好		
妹妹		
美妙		
每月		
梦		
荣		
沙漠		
上		
伤		
上海		
商谈		
身		
师傅		
诗歌		
时候		
十四		
狮子		
十八		
十五		
收缩		
手套		
书法		
舒服		
叔叔		
数学		
死亡		
四肢		
松		
素菜		
算了		
态度		
特点		
田		

	I can't read it	I don't know meaning
区域		
权威		
圈		
让		
日出		
拖鞋		
外出		
玩具		
完全		
旺		
王国		
危机		
围巾		
未来		
微笑		
纹		
温柔		
蜗牛		
握拳		
西瓜		
喜剧		
戏剧		
峡谷		
下雨		
狭窄		
象		
享		
相同		
消化		
小麦		
小猫		
消息		
心理		

	I can't read it	I don't know meaning
大		
头脑		
投资		
突出		
土豆		
突击		
学期		
学徒		
学校		
学者		
熏		
压迫		
淹		
演出		
演讲		
严厉		
演奏		
野生		
一般		
一定		
一千		
银色		
赢得		
右边		
油饼		
圆盘		
运气		
杂志		
杂货		
暂		
站		
战		
章		

	I can't read it	I don't know meaning
星		
形		
胸		
宏伟		
袖子		
学科		
祝福		
祝贺		
助手		
竹子		
捉到		
走开		
组织		
和平		
幸福		
恐惧		
晚上		
后天		
疾病		
安全		
迁居		
革新		
性别		
批评		
矛盾		
香蕉		
眼睛		
火山		
松鼠		
棕色		
服装		
滑板		
迷阵		

	I can't read it	I don't know meaning
珍珠		
正义		
指挥		
之后		
执照		
蜘蛛		
中午		

	I can't read it	I don't know meaning
车辆		
裙子		
口红		
枕头		

Questionnaire B2. Language questionnaire.

QUESTIONNAIRE

Short-term Proactive Interference Task with Chinese Words
Experiment 2
Psychology
National University of Singapore

Kindly fill up this brief questionnaire on language. The word "Chinese" includes any Chinese dialect.
Use the following scale to answer questions 1-3:

1	2	3	4	5	6	7	8	9
Exclusively English	Mostly English but Chinese in rare occasions	Frequently English but sometimes Chinese	Slightly more English than Chinese	Both languages equally	Slightly more Chinese than English	Frequently Chinese but sometimes English	Mostly Chinese but English in rare occasions	Exclusively Chinese

		score
1	In general, I speak…	
2	In general, I read in…	
3	In general, I write in…	

Rank the following questions 4-6 according to the scale below:

1	2	3	4	5
Very Low	Low	Average	High	Very High

		score
4	My proficiency at speaking Chinese (fluency) is…	
5	My proficiency at reading Chinese is…	
6	My proficiency at writing Chinese is…	

Please fill up the gaps below. Write "NO" if you did not take the subject. Please try to remember the grades, if you do not remember the grades put a "?" in the box.

Levels	**Subjects**	**Grades**	**Any remark**
O	English language		
	English literature		
	Chinese as 2nd language		
	Chinese as 1st language		
	Chinese literature		
A	General Paper		
	English literature		
	Chinese as 2nd language		
	Chinese as 1st language		
	Chinese literature		

Table B1. Cues, foils, targets and critical fillers in the phonological experimental condition of Experiment 2.

					Critical Fillers					
Cue	Foil		Target		1		2		3	
情绪 *EMOTION*	忧愁 *yōu chóu*	*sadness*	妒忌 *dù jì*	*jealousy*	右边 *yòu bian*	*right*	甲虫 *jiă chóng*	*beetle*	温柔 *wēn róu*	*gentle*
颜色 *COLOUR*	红 *hóng*	*red*	青 *qīng*	*green*	横 *héng*	*horizontal*	虫 *chóng*	*worm*	梦 *mèng*	*dream*
时间 *TIME OF DAY*	上午 *shàng wŭ*	*morning*	半夜 *bàn yè*	*midnight*	收缩 *shōu suō*	*shrink*	定义 *dìng yì*	*definition*	十五 *shí wŭ*	*fifteen*
水果类 *TYPE OF FRUIT*	苹 *píng*	*apple*	橙 *chéng*	*orange*	盘 *pán*	*dish*	民 *mín*	*people*	上 *shàng*	*top*
衣物 *ARTICLE OF CLOTHING*	裤子 *kù zi*	*pants*	夹克 *jiā kè*	*jacket*	咖啡 *kā fēi*	*coffee*	父母 *fù mŭ*	*parents*	抽屉 *chōu ti*	*drawer*
露营用具 *ITEM OF CAMPING EQUIPMENT*	背包 *bēi bāo*	*backpack*	火柴 *huŏ chái*	*matches*	补救 *bŭ jiù*	*remedy*	局部 *jú bù*	*part*	小猫 *xiăo māo*	*kitten*
车类 *TYPE OF VEHICLE*	跑车 *păo chē*	*sport car*	巴士 *bā shì*	*bus*	瀑布 *pù bù*	*waterfall*	老家 *lăo jiā*	*home*	学科 *xué kē*	*subject*
花类 *TYPE OF FLOWER*	玫瑰 *méi guī*	*rose*	百合 *băi hé*	*lily*	帽子 *mào zi*	*cap*	王国 *wáng guó*	*kingdom*	指挥 *zhĭ huī*	*conduct*
职业 *PROFESSION*	医生 *yī shēng*	*doctor*	作者 *zuò zhě*	*writer*	一般 *yī bān*	*ordinary*	大厦 *dà shà*	*edifice*	表扬 *biăo yáng*	*to praise*

房子-房间种类 *ROOM IN A HOUSE*	卧室 *wò shì*	*bedroom*	地窖 *dì jiào*	*basement*	握拳 *wò quán*	*to make a fist*	把手 *bǎ shou*	*knob*	杂志 *zá zhì*	*magazine*
四季 *SEASON OF THE YEAR*	春 *chūn*	*spring*	冬 *dōng*	*winter*	长 *cháng*	*length*	村 *cūn*	*village*	圈 *qūan*	*ring*
脸部 *PART OF A FACE*	鼻子 *bí zi*	*nose*	下巴 *xià bā*	*chin*	贝壳 *bèi ké*	*shell*	死亡 *sǐ wáng*	*death*	抽屉 *chōu ti*	*drawer*
大自然 *NATURAL EARTH FORMATION*	海洋 *hǎi yáng*	*ocean*	岩石 *yán shí*	*rock*	合作 *hé zuò*	*cooperation*	歹徒 *dǎi tú*	*ganster*	甲虫 *jiǎ chóng*	*beetle*
形状 *GEOMETRIC SHAPE*	方 *fāng*	*square*	圆 *yuan*	*circle*	粉 *fěn*	*powder*	邦 *bāng*	*state*	虫 *chóng*	*worm*
马戏团-角色 *CIRCUS ACT*	小丑 *xiǎo chǒu*	*clown*	杂技 *zá jì*	*acrobatics*	学者 *xué zhě*	*scholar*	别处 *bié chù*	*elsewhere*	助手 *zhù shǒu*	*assistant*
布料 *TYPE OF CLOTH*	丝绸 *sī chóu*	*silk*	羊毛 *yáng máo*	*wool*	素菜 *sù cài*	*veg. dish*	诗歌 *shī gē*	*poetry*	温柔 *wēn róu*	*gentle*
肉类 *TYPE OF MEAT*	猪肉 *zhū ròu*	*pork*	火腿 *huǒ tuǐ*	*ham*	正义 *zhèng yì*	*justice*	薄弱 *bó ruò*	*weak*	演奏 *yǎn zòu*	*play instr.*
运动种类 *PROFESSIONAL SPORT*	足球 *zú qiú*	*football*	游泳 *yóu yǒng*	*swimming*	杂货 *zá huò*	*groceries*	和气 *hé qi*	*polite*	潮流 *cháo liú*	*trend*
建筑 *TYPE OF BUILDING*	房屋 *fáng wū*	*house*	医院 *yī yuàn*	*hospital*	肥皂 *féi zào*	*soap*	成为 *chéng wéi*	*to become*	备注 *bèi zhù*	*remarks*
建筑材料 *BUILDING MATERIAL*	砖 *zhuān*	*brick*	钉 *dīng*	*nail*	章 *zhāng*	*chapter*	捐 *juān*	*donate*	单 *dān*	*single*

武器 *WEAPON*	枪 *qiāng*	*gun*	剑 *jiàn*	*sword*	圈 *quān*	*ring*	边 *biān*	*side*	凭 *píng*	*to rely on*
家具 *LIVING ROOM FURNITURE*	沙发 *shā fā*	*sofa*	桌子 *zhuō zi*	*table*	诗歌 *shī gē*	*poetry*	大哥 *dà gē*	*eldest brother*	爸爸 *bā ba*	*father*
农业牲口 *FARM ANIMAL*	母牛 *mǔ niú*	*cow*	火鸡 *huǒ jī*	*turkey*	秒表 *miǎo biǎo*	*stopwatch*	头脑 *tóu nǎo*	*brains*	排球 *pái qiú*	*volleyball*
啮齿动物 *TYPE OF RODENT*	老鼠 *lǎo shǔ*	*mouse*	兔子 *tù zi*	*rabbit*	雷达 *léi dá*	*radar*	老家 *lǎo jiā*	*home*	峡谷 *xiá gǔ*	*canyon*
亲属 *TYPE OF RELATIVE*	祖母 *zǔ mǔ*	*grandmother*	表妹 *biǎo mèi*	*cousin*	杂志 *zá zhì*	*magazine*	母鸡 *mǔ jī*	*hen*	肋骨 *lèi gǔ*	*rib*
罪案 *CRIME*	谋杀 *móu shā*	*murder*	偷窃 *tōu qiè*	*steal*	帽子 *mào zi*	*cap*	补救 *bǔ jiù*	*remedy*	出发 *chū fā*	*departure*
水上飞禽 *WATER BIRD*	鸭子 *yā zi*	*duck*	天鹅 *tiān é*	*swan*	压迫 *yā pò*	*oppression*	复杂 *fù zá*	*complex*	抽屉 *chōu ti*	*drawer*
树身 *PART OF A TREE*	树枝 *shù zhī*	*branch*	叶子 *yè zi*	*leaf*	诗歌 *shī gē*	*poetry*	不朽 *bù xiǔ*	*immortal*	学者 *xué zhě*	*scholar*
化学元素 *CHEMICAL ELEMENT*	氧气 *yǎng qì*	*oxygen*	水银 *shuǐ yín*	*mercury*	演奏 *yǎn zòu*	*play instrument*	赢得 *yíng dé*	*win*	代替 *dài tì*	*instead*
首饰 *PIECE OF JEWELRY*	戒指 *jiè zhi*	*ring*	手表 *shǒu biǎo*	*watch*	家具 *jiā jù*	*furniture*	大致 *dà zhì*	*approximately*	车子 *chē zi*	*car*
方向 *COMPASS DIRECTION*	东 *dōng*	*east*	南 *nán*	*south*	店 *diàn*	*shop*	空 *kōng*	*empty*	凭 *píng*	*based on*

能源 *SOURCE OF ENERGY*	电 *diàn*	*electricity*	风 *fēng*	*wind*	党 *dǎng*	*political party*	念 *niàn*	*read aloud*	勤 *qín*	*hardworking*
皇族成员 *MEMBER OF ROYALTY*	国王 *guó wáng*	*king*	太子 *tài zi*	*prince*	高度 *gāo dù*	*height*	夺得 *duó dé*	*snatch*	发扬 *fā yáng*	*develop*
冲凉房--装置 *BATHROOM FIXTURE*	厕所 *cè suǒ*	*toilet*	浴缸 *yù gang1*	*bathtub*	摧毁 *cuī huǐ*	*destroy*	十四 *shí sì*	*fourteen*	花朵 *huā duǒ*	*bloom*
畜牲 *WILD ANIMAL*	老虎 *lǎo hǔ*	*tiger*	豹子 *bào zi*	*leopard*	雷达 *léi dá*	*radar*	荷花 *hé huā*	*lotus*	雇主 *gù zhǔ*	*employer*
木匠工具 *CARPENTER'S TOOL*	锯开 *jū kāi*	*saw*	尺子 *chǐ zi*	*ruler*	教室 *jiào shì*	*classroom*	突击 *tū jī*	*rush*	球拍 *qiú pāi*	*racket*
鸟类 *BIRD OF PREY*			老鹰 *lǎo yīng*	*eagle*						
餐具 *EATING UTENSIL*			叉子 *chā zi*	*fork*						
坟地 *BURIAL PLACE*			墓地 *mù dì*	*cemetery*						
厨房用具 *KITCHEN APPLIANCE*			炉子 *lú zi*	*stove*						
鱼类 *TROPICAL FISH*			金鱼 *jīn yú*	*goldfish*						
美国-货币 *AMERICAN CURRENCY*			美元 *měi yuán*	*dollar*						
金属 *TYPE OF METAL*			钢 *gāng*	*steel*						
乳制品 *DAIRY PRODUCT*			牛奶 *niú nǎi*	*milk*						

正食	午餐	
DAILY MEAL	*wǔ cān*	*lunch*
菜类	萝卜	
VEGETABLE	*luó bo*	*radish*
酸性水果	石灰	
CITRUS FRUIT	*shí huī*	*lime*
酒类	啤酒	
KIND OF LIQUOR	*pí jiǔ*	*beer*
花生类	栗子	
TYPE OF NUT	*lì zi*	*chestnut*
乐器	吉他	
MUSICAL STRING INSTRUMENT	*jí tā*	*guitar*
时间单位	年	
UNIT OF TIME	*nián*	*year*
玩具	气球	
TOY	*qì qiú*	*balloon*
消防局器材	梯子	
PIECE OF FIREFIGHTING EQUIPMENT	*ti1 zi*	*ladder*
昆虫	蚊子	
INSECT	*wén zi*	*mosquito*

Note. The last eighteen cues, with no foil, pertain to the categories used for one-block trials.

Table B2. Cues, foils, targets and critical fillers in the visual experimental condition of Experiment 2.

Cue	Foil		Target		Critical Fillers 1		Critical Fillers 2		Critical Fillers 3	
情绪	忧愁		妒忌		怀孕		猜想		商谈	
EMOTION	*yōu chóu*	*sadness*	*dù jì*	*jealousy*	*huái yùn*	*to be pregnant*	*cāi xiǎng*	*guess*	*shāng tán*	*discuss*
颜色	红		青		纹		旺		让	
COLOUR	*hóng*	*red*	*qīng*	*green*	*wén*	*line*	*wàng*	*prosperous*	*ràng*	*permit*
时间	上午		半夜		王国		蜗牛		一千	
TIME OF DAY	*shàng wǔ*	*morning*	*bàn yè*	*midnight*	*wáng guó*	*kingdom*	*wō niú*	*snail*	*yī qiān*	*one thousand*
水果类	苹		橙		半		罕		荣	
TYPE OF FRUIT	*píng*	*apple*	*chéng*	*orange*	*bàn*	*half*	*hǎn*	*rare*	*róng*	*honor*
衣物	裤子		夹克		祈祷		美好		储存	
ARTICLE OF CLOTHING	*kù zi*	*pants*	*jiā kè*	*jacket*	*qí dǎo*	*to pray*	*měi hǎo*	*happy*	*chǔ cún*	*to store*
露营用具	背包		火柴		肯定		拒绝		银色	
ITEM OF CAMPING EQUIPMENT	*bēi bāo*	*backpack*	*huǒ chái*	*matches*	*kěn dìng*	*to confirm*	*jù jué*	*to refuse*	*yín sè*	*silver*
车类	跑车		巴士		足球		海军		冰冻	
TYPE OF VEHICLE	*pǎo chē*	*sport car*	*bā shì*	*bus*	*zú qiú*	*football*	*hǎi jūn*	*navy*	*bīng dòng*	*freeze*
花类	玫瑰		百合		收缩		赌博		心理	
TYPE OF FLOWER	*méi guī*	*rose*	*bǎi hé*	*lily*	*shōu suō*	*shrink*	*dǔ bó*	*gamble*	*xīn lǐ*	*psychological*
职业	医生		作者		区域		中午		雇主	
PROFESSION	*yī shēng*	*doctor*	*zuò zhě*	*writer*	*qū yù*	*area*	*zhōng wǔ*	*noon*	*gù zhǔ*	*employer*

房子-房间种类 *ROOM IN A HOUSE*	卧室 *wò shì*	*bedroom*	地窖 *dì jiào*	*basement*	外出 *wài chū*	*to go out*	一定 *yī dìng*	*certain*	完全 *wán quán*	*complete*
四季 *SEASON OF THE YEAR*	春 *chūn*	*spring*	冬 *dōng*	*winter*	章 *zhāng*	*chapter*	更 *gēng*	*night patrol*	身 *shēn*	*body*
脸部 *PART OF A FACE*	鼻子 *bí zi*	*nose*	下巴 *xià bā*	*chin*	复杂 *fù zá*	*complex*	算了 *suàn le*	*let it be*	基于 *jī yú*	*because of*
大自然 *NATURAL EARTH FORMATION*	海洋 *hǎi yáng*	*ocean*	岩石 *yán shí*	*rock*	每月 *měi yue4*	*monthly*	宏伟 *xióng wěi*	*grand*	备注 *bèi zhù*	*remarks*
形状 *GEOMETRIC SHAPE*	方 *fāng*	*square*	圆 *yuan*	*circle*	力 *lì*	*strength*	边 *biān*	*side*	动 *dòng*	*to move*
马戏团-角色 *CIRCUS ACT*	小丑 *xiǎo chǒu*	*clown*	杂技 *zá jì*	*acrobatics*	东西 *dōng xi*	*thing*	锯开 *jū kāi*	*saw*	按钮 *àn niǔ*	*push button*
布料 *TYPE OF CLOTH*	丝绸 *sī chóu*	*silk*	羊毛 *yáng máo*	*wool*	组织 *zǔ zhī*	*organization*	缔结 *dì jié*	*conclude*	接纳 *jiē nà*	*admit*
肉类 *TYPE OF MEAT*	猪肉 *zhū ròu*	*pork*	火腿 *huǒ tuǐ*	*ham*	猎人 *liè rén*	*hunter*	相同 *xiāng tóng*	*identical*	国内 *guó nèi*	*domestic*
运动种类 *PROFESSIONAL SPORT*	足球 *zú qiú*	*football*	游泳 *yóu yǒng*	*swimming*	捉到 *zhuō dào*	*capture*	耳环 *ěr huán*	*ear-ring*	珍珠 *zhēn zhū*	*pearl*
建筑 *TYPE OF BUILDING*	房屋 *fáng wū*	*house*	医院 *yī yuàn*	*hospital*	局部 *jú bù*	*part*	抽屉 *chōu ti*	*drawer*	结尾 *jié wěi*	*ending*
建筑材料 *BUILDING MATERIAL*	砖 *zhuān*	*brick*	钉 *dīng*	*nail*	砍 *kǎn*	*to chop*	碰 *pèng*	*to touch*	垮 *kuǎ*	*collapse*

武器 *WEAPON*	枪 *qiāng*	*gun*	剑 *jiàn*	*sword*	松 *sōng*	*pine*	疮 *chuāng*	*sore*	舱 *cāng*	*cabin*
家具 *LIVING ROOM FURNITURE*	沙发 *shā fā*	*sofa*	桌子 *zhuō zi*	*table*	秒表 *miǎo biǎo*	*stopwatch*	朋友 *péng you*	*friend*	报废 *bào fèi*	*scrap*
农业牲口 *FARM ANIMAL*	母牛 *mǔ niú*	*cow*	火鸡 *huǒ jī*	*turkey*	每月 *měi yuè*	*monthly*	中午 *zhōng wǔ*	*noon*	野生 *yě shēng*	*wild*
啮齿动物 *TYPE OF RODENT*	老鼠 *lǎo shǔ*	*mouse*	兔子 *tù zi*	*rabbit*	走开 *zǒu kāi*	*walk away*	下雨 *xià yǔ*	*rainy*	电流 *diàn liú*	*electric current*
亲属 *TYPE OF RELATIVE*	祖母 *zǔ mǔ*	*grandmother*	表妹 *biǎo mèi*	*cousin*	相同 *xiāng tóng*	*identical*	圆盘 *yuán pán*	*disk*	上海 *shàng hǎi*	*Shanghai*
罪案 *CRIME*	谋杀 *móu shā*	*murder*	偷窃 *tōu qiè*	*steal*	课本 *kè běn*	*textbook*	距离 *jù lí*	*distance*	混淆 *hùn xiáo*	*obscure*
水上飞禽 *WATER BIRD*	鸭子 *yā zi*	*duck*	天鹅 *tiān é*	*swan*	甲虫 *jiǎ chóng*	*beetle*	储存 *chǔ cún*	*to store*	美好 *měi hǎo*	*happy*
树身 *PART OF A TREE*	树枝 *shù zhī*	*branch*	叶子 *yè zi*	*leaf*	权威 *quán wēi*	*authority*	朋友 *péng you*	*friend*	报废 *bào fèi*	*scrap*
化学元素 *CHEMICAL ELEMENT*	氧气 *yǎng qì*	*oxygen*	水银 *shuǐ yín*	*mercury*	判决 *pàn jué*	*judgment*	伴侣 *bàn lǚ*	*companion*	飞机 *fēi jī*	*aeroplane*
首饰 *PIECE OF JEWELRY*	戒指 *jiè zhi*	*ring*	手表 *shǒu biǎo*	*watch*	成为 *chéng wéi*	*to become*	球拍 *qiú pāi*	*racket*	代替 *dài tì*	*instead*
方向 *COMPASS DIRECTION*	东 *dōng*	*east*	南 *nán*	*south*	紧 *jǐn*	*tight*	连 *lián*	*to link*	轮 *lún*	*wheel*
能源 *SOURCE OF ENERGY*	电 *diàn*	*electricity*	风 *fēng*	*wind*	星 *xīng*	*star*	淹 *yān*	*drown*	男 *nán*	*male*

皇族成员 *MEMBER OF ROYALTY*	国王 *guó wáng*	*king*	太子 *tài zi*	*prince*	围巾 *wéi jīn*	*scarf*	雇主 *gù zhǔ*	*employer*	中午 *zhōng wǔ*	*noon*
冲凉房--装置 *BATHROOM FIXTURE*	厕所 *cè suǒ*	*toilet*	浴缸 *yù gang1*	*bathtub*	厨师 *chú shī*	*cook*	之后 *zhī hòu*	*after*	公斤 *gōng jīn*	*kilogram*
畜牲 *WILD ANIMAL*	老虎 *lǎo hǔ*	*tiger*	豹子 *bào zi*	*leopard*	花朵 *huā duǒ*	*bloom*	态度 *tài dù*	*attitude*	白痴 *bái chī*	*idiot*
木匠工具 *CARPENTER'S TOOL*	锯开 *jū kāi*	*saw*	尺子 *chǐ zi*	*ruler*	铝箔 *lǚ bó*	*aluminium foil*	演讲 *yǎn jiǎng*	*lecture*	油饼 *yóu bǐng*	*deep-fried pancake*
鸟类 *BIRD OF PREY*			老鹰 *lǎo yīng*	*eagle*						
餐具 *EATING UTENSIL*			叉子 *cha1 zi*	*fork*						
坟地 *BURIAL PLACE*			墓地 *mù dì*	*cemetery*						
厨房用具 *KITCHEN APPLIANCE*			炉子 *lú zi*	*stove*						
鱼类 *TROPICAL FISH*			金鱼 *jīn yú*	*goldfish*						
美国-货币 *AMERICAN CURRENCY*			美元 *měi yuán*	*dollar*						
金属 *TYPE OF METAL*			钢 *gāng*	*steel*						
乳制品 *DAIRY PRODUCT*			牛奶 *niú nǎi*	*milk*						
正食 *DAILY MEAL*			午餐 *wǔ cān*	*lunch*						

菜类 *VEGETABLE*	萝卜 *luó bo*	 *radish*
酸性水果 *CITRUS FRUIT*	石灰 *shí huī*	 *lime*
酒类 *KIND OF LIQUOR*	啤酒 *pí jiǔ*	 *beer*
花生类 *TYPE OF NUT*	栗子 *lì zi*	 *chestnut*
乐器 *MUSICAL STRING INSTRUMENT*	吉他 *jí tā*	 *guitar*
时间单位 *UNIT OF TIME*	年 *nián*	 *year*
玩具 *TOY*	气球 *qì qiú*	 *balloon*
消防局器材 *PIECE OF FIREFIGHTING EQUIPMENT*	梯子 *ti1 zi*	 *ladder*
昆虫 *INSECT*	蚊子 *wén zi*	 *mosquito*

Note. The last eighteen cues, with no foil, pertain to the categories used for one-block trials.

Table B3. List of words and nonwords for the lexical decision task.

Words		Nonwords	
Abstract	Concrete	Standard	Special
暴力	把手	白 注	裱值
悲剧	报纸	报酒	叉弧
比赛	贝壳	表处	翅到
补救	歹徒	不壶	地节
耻辱	肚子	长为	冬误
定义	肥皂	车莓	俘昊
合作	蝴蝶	出辱	工语
嫉妒	课本	发博	骨泪
歧视	辣椒	父皂	雇值
死亡	朋友	歌烧	荷砝
未来	手套	国独	肌汽
正义	杂志	海法	叫市
祝福	竹子	火肉	辣舳
和平	香蕉	结格	每庙
幸福	眼睛	舅道	美乐
恐惧	火山	距啡	目才
晚上	松鼠	咖绝	歧济
后天	棕色	老烛	师割
疾病	服装	肋椒	头仔
安全	滑板	排地	完据
迁居	迷阵	十法	维金
革新	车辆	头点	危肖
性别	裙子	蜗瓜	狭古
批评	口红	学出	晓迈
矛盾	枕头	严迫	祝首